Enclosure 1

Change Pages for Mixed Oxide Fuel Fabrication Facility Construction Authorization Request

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LIST OF ACRONYMS AND ABBREVIATIONS (continued)

EC	effluent concentration
ECR	Engineering Change Request
EDMS	Electronic Data Management System
EDST	Eastern Daylight Savings Time
EIS	Environmental Impact Statement
EMMH	external man-made hazard
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration
ERPG	Emergency Response Planning Guidelines
ES&H	Environment, Safety, and Health
ETF	Effluent Treatment Facility
FA	flame acceleration
FEM	finite element model
FEMA	failure modes and effect analysis
FHA	Fire Hazard Analysis
FIC	final isotopic composition
FM	Factory Mutual
FOCI	foreign ownership, control, or influence
fpm	feet per minute
ft	foot
g	gram
g	acceleration due to gravity
gal	gallon
gpm	gallons per minute
GSA	General Separations Area
GSAR	Generic Safety Analysis Report
GSG	geological, seismological, geotechnical
ha	hectare
HAN	hydroxylamine nitrate
HAZOP	hazards and operability study
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
HEPA	high-efficiency particulate air
HFE	human factors engineering
HIS	Human-system interface
HLW	high-level waste
HP	Health Physics
HPLC	high performance liquid chromatography
hr	hour
HVAC	heating, ventilation, and air conditioning
Hz	hertz
I&C	instrumentation and control
I/O	input/output

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

IAEA	International Atomic Energy Agency
ICBO	International Conference of Building Officials
ICP-MS	inductive coupled plasma – mass spectroscopy
ID	identification
IDLH	Immediately Dangerous to Life and Health
IEEE	Institute of Electrical and Electronic Engineers
IOC	Individual Outside the MFFF Controlled Area
in	inch
INES	International Nuclear Event Scale
IROFS	items relied on for safety
ISA	Integrated Safety Analysis
IT/SF	Interim Treatment/Storage Facility
ITP	In-Tank Precipitation Facility
ka	kilo annum or thousands of years
kg	kilogram
kip	kilopound
km	kilometer
kV	kilovolt
L	liter
lb	pound
LDE	Lens of the Eye Dose Equivalent
LETF	Liquid Effluent Treatment Facility
LFL	lower flammable limit
LLC	Limited Liability Company
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LOC	level of severity or concern
LPF	leak path factor
LWR	light water reactor
m	meter
M	molar
M&O	Maintenance and Operations
m^3	cubic meter
Ma	mega annum or millions of years
MACCS2	MELCOR Accident Consequence Code System for the Calculation of the Health and Economic Consequences of Accidental Atmospheric Radiological Releases
MAR	material at risk
mb	body wave magnitude
mbar	millibar
MBP	monobutyl phosphate
MC&A	Material Control and Accounting
MCC	motor control center
MCNP	Monte Carlo N-Particle
MD	duration magnitude

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1. GENERAL INFORMATION

1.1 FACILITY AND PROCESS OVERVIEW

1.1.1 Introduction

The consortium of Duke Project Services Group, Inc., COGEMA Inc., and Stone & Webster, Inc., has formed a Limited Liability Company (LLC) called Duke Cogema Stone & Webster (DCS). DCS seeks authorization to construct a Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) for the U.S. Department of Energy (DOE) on DOE's Savannah River Site (SRS) near Aiken, South Carolina. The MFFF is designed to convert surplus weapons-grade plutonium to MOX fuel that can be used to generate electricity at commercial nuclear power stations. The fabrication of the MOX fuel, which is a blend of uranium and plutonium oxides, is based on the proven European technology of COGEMA and BELGONUCLEAIRE.

If there are relevant changes following submittal of this request for construction authorization, the facility and process overview will be updated with the license application for possession and use of special nuclear material (SNM).

1.1.2 General Facility Description

The MFFF is located in F Area of SRS as indicated in Figure 1.1-1. The arrangement of the buildings and facilities of the MFFF is shown in Figure 1.1-2.

The MFFF site comprises an area of approximately 41 ac (16.6 ha). Approximately 17 ac (6.9 ha) of the site are developed with buildings, facilities, or paving. The remaining 24 ac (9.7 ha) are landscaped in either grass or gravel. No highways, railroads, or waterways traverse the MFFF site, and the movement of material and personnel to and from the MFFF site takes place via the SRS internal road system. Transportation right-of-ways are shown on Figure 1.1-1. The public transportation right-of-way nearest to the MFFF site and F Area is South Carolina Route (SCR) 125 to the west. Access to the MFFF site is via SRS Roads C and C-3.

1.1.2.1 Controlled Area Boundary

In accordance with 10 CFR §70.61(f), a licensee must establish a controlled area, as defined in 10 CFR §20.1003, and retain the authority to exclude or remove personnel and property from the area. A *controlled area* is an area outside of a restricted area but inside the site boundary to which access can be limited by the licensee for any reason. A *restricted area* is an area to which access is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. The MFFF restricted area is coincident with the protected area, an area encompassed by physical barriers and to which access is controlled. The MFFF site is under DCS control and includes the restricted area, the receiving warehouse, the administration building, the MFFF parking lot, and the gas storage area. Herein, *controlled area boundary* is established at the MFFF site perimeter. The restricted area and controlled area are shown on Figure 1.1-2, MFFF Site Layout.

The controlled area boundary is approximately 525 ft (160 m) from the MFFF building stack. For calculational purposes, a MFFF facility worker (facility worker) is considered to be within the MFFF located inside a room near a potential accident release point. A MFFF site worker (site worker) is considered to be 328 ft (100 m) from the MFFF building stack. Both site workers and facility workers are subject to the "worker" performance requirements of 10 CFR 70.61.

10 CFR Part 70 also establishes performance requirements for individuals located outside the MFFF Controlled Area. The Individual Outside the MFFF Controlled Area (IOC) is a hypothetical individual located outside the MFFF Controlled Area either on or off the Savannah River Site. DCS will meet the performance requirements of 10 CFR 70.61(b)(2), (b)(3), (b)(4)(ii), (c)(2), and (c)(4)(ii) for the IOC. The IOC located on the Savannah River Site is subject to DOE regulations, directives and orders issued pursuant to DOE jurisdiction and authority. The IOC would not be considered a MFFF "facility worker" or MFFF "site worker" as those terms are used herein.

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DCS intends to establish a protocol with the U.S. Department of Energy to provide for integration with the existing SRS controls established for general public access to the site.

1.1.2.2 MOX Fuel Fabrication Building

The MOX Fuel Fabrication Building (BMF) is a multifunctional complex containing all of the plutonium oxide (PuO_2) handling, fuel processing, and fuel fabrication operations of the MFFF. The building is a reinforced-concrete structure with a gabion security barrier provided outside the structural walls and roof. The overall roof height of BMF is a common elevation of 73 ft (22.3 m) above grade. The 40-ft (12.2-m) tall Vent Stack, located on top of the BMF, has a top elevation of approximately 119 ft (36.3 m) above grade.

The MOX Fuel Fabrication Building is comprised of three major functional, interrelated areas: the MOX Processing Area (BMP), the Aqueous Polishing Area (BAP), and the Shipping and Receiving Area (BSR). The MOX Processing Area includes the blending and milling area, pelletizing area, sintering area, grinding area, fuel rod fabrication area, fuel bundle assembly area, a laboratory area, and storage areas for feed material, pellets, and fuel assemblies. Space is also provided in the MOX Fuel Fabrication Building for support equipment, such as temporary waste storage; heating, ventilation, and air conditioning (HVAC) equipment; high-efficiency particulate air (HEPA) filters plenums; inverters; switchgear; and pumps.

1.1.2.3 Emergency Generator Building

The Emergency Generator Building (BEG) contains the emergency diesel generators that provide the emergency onsite electrical power supply for loads that are principal structures, systems, or components (SSCs) in the MFFF. The Emergency Generator Building is a single-story, slab-on-grade, reinforced-concrete building located adjacent to the MOX Fuel Fabrication

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FIGURE DELETED

Figure 1.1-3. Controlled Area Boundary

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1.2 INSTITUTIONAL INFORMATION

The institutional information provided herein will be updated as appropriate in the license application for possession and use of SNM.

1.2.1 Corporate Identity

Duke Cogema Stone & Webster, LLC (DCS) is the applicant for the license to possess and use special nuclear material (SNM). DCS is registered in the State of South Carolina as a Limited Liability Company (LLC) owned by Duke Project Services Group, Inc. (DPSG), COGEMA, Inc., and Stone & Webster, Inc. (S&W). These three companies are the equity owners of the LLC (DPSG 40%, COGEMA 30%, and S&W 30%). DCS was formed to provide MOX fuel fabrication and other services to support the mission of DOE for the disposition of U.S.-owned surplus weapons-usable plutonium. The applicant's mailing address is as follows:

Duke Cogema Stone & Webster
P.O. Box 31847
Charlotte, NC 28231-1847

The applicant's shipping address is as follows:

Duke Cogema Stone & Webster
128 South Tryon Street, FC12A
Charlotte, NC 28202

DOE will be the owner of the MFFF, which will be located at SRS in Aiken, South Carolina. DCS is a South Carolina LLC whose direct owners are all U.S. corporations. All DCS principal officers are U.S. citizens. COGEMA, Inc., which owns a minority share of DCS (30%), is itself a wholly owned subsidiary of COGEMA, SA, a French company. DPSG and S&W together hold a 70% majority interest in DCS. As a result, there is no direct foreign ownership, no foreign control, and no significant foreign interest in DCS. Furthermore, in awarding the contract to DCS to design, construct, and operate the MFFF, DOE engaged in a careful foreign ownership, control, or influence (FOCI) review of its own in accordance with DOE Order 470.1, "Safeguards and Security Program." Based upon that review, DOE rendered a favorable FOCI determination on 9 July 1999, based on a Security Control Agreement between Duke Cogema Stone & Webster, LLC and DOE, mitigating Foreign Ownership, Control, or Influence associated with Duke Cogema Stone & Webster, LLC. Additionally, favorable FOCI determinations have been made for Duke Project Services Group (10 June 2002) and Stone & Webster, Inc (through reciprocity with the Department of Defense).

The principal DCS corporate officers (and citizenship), and their addresses, are as follows:

L. Ron Barnes (USA)
President and Chief Operating Officer
Duke Cogema Stone & Webster
128 South Tryon Street, FC12A
Charlotte, NC 28202

Thomas E. Touchstone (USA)
Vice President Plans, Metrics, Support Services
Duke Cogema Stone & Webster
128 South Tryon Street, FC12A
Charlotte, NC 28202

Edward J. Brabazon (USA)
Vice President, Engineering Services
Duke Cogema Stone & Webster
128 South Tryon Street, FC12A
Charlotte, NC 28202

Naresh C. Jain (USA)
Secretary/Treasurer
Duke Cogema Stone & Webster
128 South Tryon Street, FC12A
Charlotte, NC 28202

Corwin R. Bishop (USA)
Vice President, Construction Services
Duke Cogema Stone & Webster
128 South Tryon Street, FC12A
Charlotte, NC 28202

DCS is completely responsible for the design, construction management, and operation of the MFFF. In addition to the DPSG and S&W engineering expertise, the following companies provide technical support:

- Belgonucleaire (BN) for MOX fuel process design, facility design, and operations experience
- SGN, a wholly owned subsidiary of COGEMA, for facility design and operations experience
- Framatome ANP for operations and engineering experience
- Nuclear Fuel Services, Inc. for Safeguards and Security experience.

1.2.2 Type and Period of License and Type, Quantity, and Form of Licensed Material

DCS intends to request a license to receive, acquire, possess, use, store, and transfer byproduct material, source material, and SNM. The requested period of the license is 20 years.

Authorization is intended for the types, maximum quantities, and forms of byproduct material, source material, and SNM provided in Table 1.2-1. The possession limits in Table 1.2-1 will be updated at the time of license application for possession and use of SNM and source and byproduct materials.

In 2002, SRS employed approximately 13,590 persons, including 12,051 employed by WSRC (Management and Operations [M&O] Contractor); 823 employed by Wackenhut Services Inc. (WSI); 459 employees under DOE-SR; and 257 other SRS contract employees. As shown in Table 1.3.2-9, approximately 90% of that workforce resides within five counties: Aiken, Barnwell, and Edgefield Counties in South Carolina and Columbia and Richmond Counties in Georgia.

1.3.2.2 Population Centers

The MFFF site within SRS is extremely rural, is entirely within the boundaries of the SRS property, and contains no communities, neighborhoods, or other areas that may be impacted by MFFF operations. The nearest population is located more than 5 mi (8 km) from the MFFF site.

A majority of the population within a 10-mi (16-km) radius of the MFFF site resides within Aiken County. Additional population information is provided in Section 1.3.2.1.

1.3.2.3 Public Facilities

1.3.2.3.1 School Population

A minimal number of facilities, mostly schools, containing transient populations are located within a 10-mi (16-km) radius surrounding the MFFF site. Five public schools are located within the area to the northwest and west, with the closest being over 6 mi (9.6 km) away from the MFFF site. Table 1.3.2-10 lists local public schools within the 10-mi (16-km) radius of the MFFF site and recent enrollments (1998 to 1999). The schools operate for 180 days each year, from late August through late May. There are no private schools or colleges located in the 10-mi (16-km) radius of the MFFF site. The students in these schools are assumed to be part of the resident population within the 50-mi (80-km) radius of the MFFF site.

1.3.2.3.2 Health Care Populations

The U.S. Census Bureau estimated that 1,765 people resided in group quarters in Aiken County, 297 in Barnwell County, and 216 in Burke County in 1997. The only residential institutions classified as "group quarters" within 10 mi (16 km) of the site are three residential care facilities located in New Ellenton: the New Ellenton Nursing Center (26 beds), Coleman's Residential Care (10 beds), and Parker's Residential Care Home (nine beds). The closest of these three facilities, Parker's Residential Care Home, is outside of the 6-mi (9.6-km) radius northwest of the MFFF site. There are no hospitals located within a 6-mi (9.6-km) radius of the MFFF site.

1.3.2.3.3 Recreational Population

The primary recreational activity within a 5-mi (8-km) radius of the MFFF site is controlled sport hunting. Hunts at SRS, supervised by DOE, are conducted annually with the benefit of controlling deer and feral hog populations.

Hunting also takes place at Crackerneck, an area of 4,780 ac (1,934 ha) west of SRS in Aiken County. The South Carolina Department of Natural Resources (SCDNR) manages hunts at

Crackerneck for deer, hogs, small game, and waterfowl, although permits are issued by DOE. Another sporting area within 5 mi (8 km) of SRS is a private commercial area of 4,000 ac (1,619 ha) about 15 mi (24 km) east of Waynesboro, Georgia. Hunting and/or fishing, as well as available lodging, are available to the public all year for a fee. No records of usage are available.

Additional recreational usage near the vicinity is available at three state parks located outside of the 5-mi (8-km) radius of SRS production areas but within the 12-mi (19-km) radius of the SRS site boundary. These areas include Redcliffe State Park, a historic site located off SCR 278 at Beech Island; Aiken State Park located off U.S. Route 78, 16 mi (25 km) east of Aiken; and Barnwell State Park located off SCR 3 near Blackville. During fiscal year 1994/1995, total park usage was approximately 116,000 visitor-days. All of the parks are available to the public year-round.

Other recreational activities within the 5-mi (8-km) radius of SRS production areas include fishing and boating. Numerous boat landings are located on the west bank of the Savannah River, which borders the southwestern portion of the site. In addition, a 95-ac (38.4-ha) man-made lake, Lake Edgar Brown, is located within the city limits of Barnwell. No records of usage at these areas are available.

1.3.2.4 Industrial Areas

1.3.2.4.1 Savannah River Site Operations Activities

SRS consists of six major operating areas: reactor areas (C, K, L, P, and R Areas); separations areas (F and H Areas); waste management areas (E, S, and Z Areas); heavy water reprocessing area (D Area); reactor materials area (M Area); and administration area (A Area).

1.3.2.4.1.1 Reactor Areas (C, K, L, P, and R Areas)

The five nuclear production reactor facilities (C, K, L, P, and R Reactors) occupy 934 ac (378 ha) of SRS. All five reactors are located within a 10-mi (16-km) radius of the MFFF site and have been placed in cold shutdown with no plans for restart. The approximate locations of the reactor areas are shown in Figure 1.3.2-2. Although the reactor areas are being used for moderator and fuel storage, no effort is being expended to maintain the production capability of these reactors.

1.3.2.4.1.2 F Area

F Area is located in Aiken County, South Carolina, near the center of SRS, east of SRS Road C and north of SRS Road E (see Figure 1.3.2-2). The existing F Area occupies 364 ac (147 ha). The F-Area center point coordinates are given in Table 1.3.1-2. The nearest SRS site boundary to F Area is less than 6 mi (9.5 km) to the west.

F-Area's main processing facility is F Canyon, which is composed of two chemical separation plants and associated waste storage facilities. In the past, F Canyon was used to chemically separate uranium, plutonium, and fission products from irradiated fuel and target assemblies. The separated uranium and plutonium were transferred to other DOE facilities for further

1.3.5 Geology

1.3.5.1 Regional Geology

The following discussion on the regional and MFFF site geology is based on detailed discussions presented in Section 1.4.3 of the *Natural Phenomena Hazards (NPH) Design Criteria and Other Characterization Information for the Mixed Oxide (MOX) Fuel Fabrication Facility at Savannah River Site (U)* (WSRC 2000b) and in the *MOX Fuel Fabrication Facility Site Geotechnical Report* (DCS 2003). The area of interest evaluated includes a radius of about 200 mi (322 km) from SRS and the MFFF site. The information also provides the basis for understanding the regional and SRS geology as applied to the subsurface encountered at the MFFF site.

Many SRS investigations and an extensive literature review have been used to reach the conclusion that there are no geologic threats affecting the MFFF site, except the Charleston Seismic Zone and the minor random Piedmont earthquakes. Although the Pen Branch fault has been regarded as the primary structural feature at SRS that has the characteristics necessary to pose a potential seismic risk, studies have indicated that the fault is not capable.

The southeastern continental margin, within a 200-mi (322-km) radius of SRS, contains portions of all the major divisions of the Appalachian orogen (mountain belt) in addition to the elements that represent the evolution to a passive margin.

Within the Appalachian orogen, several lithotectonic terranes that have been extensively documented include the foreland fold belt (Valley and Ridge) and western Blue Ridge Precambrian-Paleozoic continental margin; the eastern Blue Ridge-Chauga Belt-Inner Piedmont terrane; the volcanic-plutonic Carolina terrane; and the geophysically defined basement terrane beneath the Atlantic Coastal Plain (see Figure 1.3.5-1). These geological divisions record a series of compressional and extensional events that span the Paleozoic. The modern continental margin includes the Triassic-Jurassic rift basins that record the beginning of extension and continental rifting during the early to middle Mesozoic. The offshore Jurassic-Cretaceous clastic-carbonate bank sequence covered by younger Cretaceous and Tertiary marine sediments, and onshore Cenozoic sediments represent a prograding shelf-slope and the final evolution to a passive margin. Other offshore continental margin elements include the Florida-Hatteras shelf and slope and the unusual Blake Plateau basin and escarpment.

From the Cumberland Plateau and the Valley and Ridge provinces to the offshore Blake Plateau basin, the regional geology records the complete cycles of opening and closing of Paleozoic oceans and the opening of a new ocean (Atlantic). Late Proterozoic rifting is recorded in rift-related sediments at the edge of the frontal Blue Ridge province and the Ocoee and Tallulah Falls basins in the western and eastern Blue Ridge, respectively. Passive margin conditions began in the middle Cambrian and persisted through early Ordovician. The Cambro-Ordovician sedimentary section in the Valley and Ridge reflects this condition. The collision-accretionary phase of the Appalachians began in the middle Ordovician and persisted with pulses through the early Permian. Mesozoic rifting of the continents led to the creation of Triassic rift basins on the modern eastern continental margin and ultimately to the creation of the Atlantic Ocean basin. The evolution to a passive margin is recorded in the Cretaceous through Holocene Coastal Plain sediments and offshore carbonate bank and shelf sequences.

The two predominant processes sculpting the landscape during this tectonically quiet period included erosion of the newly formed highlands and subsequent deposition of the sediments on the coastal plain to the east. The passive margin region consists of a wedge of Cretaceous and Cenozoic sediments that thicken from near zero at the Fall Line to about 1,100 ft (335 m) in the center of SRS, and to approximately 4,000 ft (1,220 m) at the South Carolina coast. The fluvial to marine sedimentary wedge consists of alternating sand and clay with tidal and shelf carbonates common in the downdip Tertiary section.

1.3.5.1.1 Valley and Ridge Province

The Valley and Ridge Province (see Figure 1.3.5-1) includes Paleozoic sedimentary rocks consisting of conglomerate, sandstone, shale, and limestone. The shelf sequence was extensively folded and thrust faulted during the Alleghanian collisional event. The physiography is expressed as a series of parallel ridges and valleys that are a result of the erosion of breached anticlines with the oldest layers exposed in the valleys and the younger layers forming the ridges. The topographic expression of the folds is best expressed in the central and southern Appalachians. In the central and northern Appalachians the folded structure is dominant and thrust faults are not as numerous or expressed at the surface. The eastern boundary with the Blue Ridge province is formed by the Blue Ridge-Piedmont thrust. This boundary is distinct in most places along the strike of the Appalachians and marks the change from folded rocks that are not penetratively deformed to rocks that are penetratively deformed.

1.3.5.1.2 Blue Ridge Province

The Blue Ridge geologic province is bounded on the southeast by the Brevard fault zone and on the northwest by the Blue Ridge-Piedmont fault system (see Figure 1.3.5-1). The province is a metamorphosed basement/cover sequence that has been complexly folded, faulted, penetratively deformed, and intruded. These rocks record multiple late Proterozoic to late Paleozoic deformation (extension and compression) associated with the formation of the Iapetos Ocean and the Appalachian orogen. The province consists of a series of westward-vergent thrust sheets, each with different tectonic histories and different lithologies (including gneisses, plutons, metavolcanic, and metasedimentary rift sequences), as well as continental and platform deposits. The Blue Ridge-Piedmont fault system thrust the entire Blue Ridge province northwest over Paleozoic sedimentary rock of the Valley and Ridge province during the Alleghanian orogeny. The Blue Ridge geologic province reaches its greatest width in the southern Appalachians.

The Blue Ridge is divided into a western and an eastern belt separated by the Hayesville-Gossan Lead fault. Thrust sheets in the western Blue Ridge consist of a rift-facies sequence of clastic sedimentary rocks deposited on continental basement, whereas thrust sheets in the eastern Blue Ridge consist of slope and rise sequences deposited in part on continental basement and in part on oceanic crust. Western Blue Ridge stratigraphy consists of basement gneisses, metasedimentary, metaplutonic, and metavolcanic rocks, whereas Eastern Blue Ridge stratigraphy consists of fewer lithologies, more abundant mafic rocks, and minor amounts of continental basement. These divisions of the Blue Ridge are discussed in more detail below.

Qal 2, and Qt. The reworked sediments are derived from the uppermost Coastal Plain sediments and effectively cover up the deepest formations exposed in the stream valley bottoms.

Contacts separating the geological formations were mapped by examination of natural and manmade surface exposures and from subsurface drill core. Original compilation of field data was done at 1:100,000 scale. The subsequent SRS map is presented at 1:48,000 scale.

1.3.5.2 MFFF Site Geology

In calendar year 2000, 13 exploration borings and 63 CPT holes were used to define site-specific subsurface conditions at the MFFF site. Additional site geotechnical programs previously performed by others adjacent to and on this site were also used to evaluate site subsurface geologic and groundwater conditions. A detailed description of subsurface conditions encountered and previous SRS geotechnical references used for this investigation are described in detail in the *MOX Fuel Fabrication Facility Site Geotechnical Report* (DCS 2000). Exploration boring logs, CPT logs, and initial soil classification test results are also presented in this report. The location of exploration borings and CPT holes used to investigate the MFFF site are shown on Figure 1.3.5-22.

Information available from previous subsurface investigations was instrumental in development of the MFFF geotechnical field exploration program. Results of geotechnical exploration for the Actinide Packaging and Storage Facility (APSF), located adjacent to and south of the MFFF site, revealed the presence of subsurface soft zones. The *F-Area Northeast Expansion Report* (WSRC 1999b) contains results of additional explorations performed in the same vicinity, including the MFFF site area, that indicate that subsurface conditions at the MFFF site are similar to those previously encountered at APSF and nearby areas.

Initial layout of the CPT program for the MFFF site was patterned after the CPT layout that ultimately proved successful in adequately locating potential soft soil zones at the APSF site. As soft zones were encountered on the MOX site during field explorations, additional CPT and exploration holes were added to the plan to identify and delineate the extent of the soft zones found. The resulting CPT and exploration hole spacing, when combined with ones from previous explorations in the same area, was of greater concentration than was initially deemed necessary. The resulting data collection was found to be quite sufficient to identify potential loose soil zones that may be subject to liquification (see Section 1.3.7), as well as the soft zones present. Once the location and extent of the soft zones on the MFFF site were identified, the MFFF principal SSCs, such as the MOX Fuel Fabrication Building and the Emergency Diesel Generator Building were relocated to areas of the site found to be free of soft zones.

The approach for the layout of CPTs and exploration borings at the MFFF site provides confidence that soft and loose soil zones have been effectively identified in the vicinity of MFFF principal SSCs. Exploration spacing in the original geotechnical investigation was greater than desired because the drilling and CPT rigs could not access locations on the existing APSF spoils pile berm slopes. Grading of the slopes was performed in the summer of 2001 so that rig access could be provided to additional exploration hole locations. During the summer of 2002, DCS conducted a supplemental geotechnical investigation to acquire additional subsurface information to provide increased confidence that the size and extent of soft zones beneath the

MFFF principal SSCs are adequately characterized. The results of these supplemental investigations are consistent with the results obtained during the initial site investigations, and they are described in detail in the *MOX Fuel Fabrication Facility Site Geotechnical Report* (DCS 2003).

The CPT holes extended from approximately 64 to 140 ft (19.5 to 42.7 m) below present site grade. Each CPT hole provided a continuous profile of the soil conditions encountered at each test location. Seismic, resistivity, and piezometric measurements were obtained in many of the CPT holes. Some soft soil zones related to past solution and deposition activity were identified at depth on the MFFF site. The soft zones encountered were typical to those that have been described in previous F-Area investigations. The CPT holes were used to define limits of the soft zones. MFFF principal SSCs, the MOX Fuel Fabrication Building, and the Emergency Diesel Generator Building were adjusted on the MFFF site so that they are not directly over any identified thick soft zones and to minimize the potential impact of the underlying soft zones. Both static and dynamic analyses have been performed to evaluate the effect of soft zones near MFFF principal SSCs. The location of facilities at the MFFF site is shown on Figure 1.3.5-22.

Subsurface soils at the MFFF site have also been evaluated to determine whether they have any potential for liquefaction during the design basis earthquake event. The potential for liquefaction has been determined using the established groundwater levels for the MFFF site, laboratory, geophysical, and cone penetration test results, and blow count data from exploration borings.

Recognized industry practice methods used to define and determine the potential for liquefaction have been utilized. The design basis earthquake has been used to establish the potential for liquefaction. Section 1.3.7.1 describes these evaluations.

The soil exploration borings extend from approximately 131 to 181 ft (39.1 to 55.2 m) below the present site grade. The exploration borings were used for correlation with the CPT holes and to obtain soil samples for laboratory testing. Three cased holes (exploration borings BH-2, BH-5, and BH-10) from the exploration program were used for downhole seismic testing.

The exploration borings and CPT holes indicate that subsurface conditions encountered at the MFFF site are consistent with all previous investigations performed at SRS in F Area, at and near the site. No unusual subsurface geological or groundwater hydrologic conditions were encountered. Representative geotechnical cross sections at the MFFF site are shown on Figures 1.3.5-23, -24, and -25.

The upper geologic units at the MFFF site are composed of the Barnwell Group. The exploration borings also extended through the Tinker/Santee Formation, Warley Hill Formation, and into the very dense Congaree Formation of the Orangeburg Group. Table 1.3.5-1 presents the correlation of geologic units and engineering units presently being used for geotechnical investigations at SRS. This correlation has been adopted for this geotechnical program, to be consistent with other SRS references being used for the MFFF site. The engineering units shown on Figures 1.3.5-23, -24, and -25 are consistent with the correlation shown on Table 1.3.5-1 and the geologic units discussed in this section and the referenced reports.

The upper groundwater level is within the Upper Three Runs aquifer and as described in Section 1.3.4.2. Based on the results of pore water pressure dissipation testing, the groundwater level at

1.3.6.3.5 WSRC (PC-3 and PC-4 Sitewide Design Spectra)

The sitewide design spectra fully implement DOE-STD-1023-95 (DOE 1996b). DOE-STD-1023-95 specifies a broadened mean-based UHS representing a specified annual probability of exceedance (for an SSC performance category) and a historical earthquake deterministic spectrum that ensures breadth of the UHS. For SRS, the deterministic spectrum is represented by a repeat of the 1886 Charleston earthquake. The development of the SRS design basis spectra uses a statistical methodology to verify that a mean-based response is achieved at the soil free surface.

The design spectra were intended for simple response analysis of SSCs and are not appropriate for soil-structure interaction analysis or geotechnical assessments. The design basis spectra for PC-3 and PC-4 are given in Figures 1.3.6-13 and 1.3.6-14, respectively.

The EPRI and LLNL bedrock level uniform hazard spectra were averaged and broadened in accordance with DOE-STD-1023-95 (DOE 1996b). Available SRS soil data were used to parameterize the soil shear-wave velocity profile. The parameterization was used to establish statistics on site response for ranges of soil column thickness present at SRS. The mean soil UHS was obtained by scaling the bedrock UHS by the ground motion dependent mean site amplification functions.

The soil data used to develop the sitewide spectra incorporate the available SRS velocity and dynamic property database available to about mid-1996. The spectra are based on soil properties and stratigraphy from specific locations at SRS and are parameterized to represent the variability in measured properties. Because of the potential for variation of soil properties in excess of what have been measured at SRS, the design basis spectra are issued as "committed" for DOE facilities at SRS. The open item is the soil column variability used in the calculations. The soil parameters for the MFFF site have been checked for consistency with the data parameterized in the study, and the spectra have been confirmed to be applicable to the MFFF.

DOE PC-3 and PC-4 design spectra are compared to the SRS interim spectrum and the Blume envelope spectrum (Figure 1.3.6-15). There is broad general agreement between the PC-3 and interim spectral shape. The SRS interim spectrum shape is significantly more conservative in the frequency range of 0.5 to 2.0 Hz compared to the PC-3 spectrum because the interim shape enveloped the 84th percentile Charleston deterministic spectrum rather than the 50th percentile as required by DOE-STD-1023-95 (DOE 1996b). Comparisons of the Blume 0.20g anchored spectrum to the PC-3 design spectrum indicate significant shape differences. The Blume spectrum was derived from deep soil recordings of western U.S. earthquakes and is not representative of eastern United States spectral shapes. The spectra show a generally more broadened shape as compared to the Blume spectra (see Figure 1.3.6-15). Low frequencies are enhanced with respect to Blume because the Blume spectra do not contain the fundamental site resonance (about 0.6 Hz). High frequencies are also enhanced with respect to Blume because of the difference in eastern and western United States attenuative properties. Both the PC-3 spectrum and the Blume spectrum have a dynamic amplification of about 2.7 at 3 Hz. The significantly larger Blume PGA scaling factor causes the excess (as compared to the design basis spectrum) spectral values at the mid-range.

1.3.6.3.6 WSRC (PC-1 and PC-2 Sitewide Design Spectra)

Design spectra guidelines for DOE PC-1 and PC-2 facilities are reported by Lee (1998). The DOE PC-1 and PC-2 design spectra were derived using DOE-STD-1023-95 guidelines and NEHRP-97 (BSSC 1997) design criteria and account for the wide range in SRS material properties and geometries including soil shear-wave velocities, uncertainty or range in soil column thickness, and type of basement material. Additional design guidance is contained in the current revision of WSRC Engineering Standard 01060 (WSRC 1999a).

1.3.6.3.6.1 SRS-Specific Probabilistic Seismic Hazard Assessments

An SRS-specific PSHA was developed using bedrock outcrop EPRI and LLNL hazard and SRS site properties including soil column thickness, soil and bedrock shear-wave velocity, and dynamic properties. The *MOX Fuel Fabrication Facility Site Geotechnical Report* (DCS 2003) contains a detailed presentation of the site investigations that have been conducted and the results of site-specific analyses. Section 3.4 of DCS 2003 also demonstrates the applicability of the SRS site generic PSHA to the MFFF site. Section 5.0 of DCS 2003 presents subsurface conditions at the MFFF site and demonstrates that they are consistent with subsurface conditions that exist at the adjacent F Area at SRS. Section 6.2 of DCS 2003 presents dynamic properties for the subsurface soils and the one-dimensional free-field response analyses for the MFFF site. Consequently, another PSHA specific to the MFFF site is not required.

The bedrock seismic hazard evaluations used for the SRS-specific soil surface hazard were the EPRI and LLNL results for bedrock for SRS and vicinity. These evaluations did not revise or confirm in any way the experts' evaluations of activity rates, seismic source zonation, or the decay of ground motion with distance used in the LLNL or EPRI seismic hazard assessments. The analysis results in an SRS-specific hazard evaluation for a soil site by continuing the hazard from bedrock to the soil surface using detailed soil response functions. Earthquake magnitude and ground motion level dependence of the site response are accommodated by applying site response functions consistent with the distribution of earthquake magnitude and ground motion levels obtained from disaggregating the bedrock uniform hazard spectrum.

Frequency and ground motion level dependent soil amplification functions developed in WSRC-TR-97-0085 (Lee et al. 1997) were used to account for the observed variations in properties throughout SRS, including soil column thickness, stratigraphy, shear-wave velocity, and material dynamic properties, as well as basement properties. Soil amplification functions (frequency-dependent ratio of soil response to bedrock input) were derived in WSRC-TR-97-0085 (Lee et al. 1997) by performing a statistical analysis of the response of bedrock spectra through realizable soil columns bounded by the observed variations in soil-column properties over SRS. Ground motion level-dependent distributions of soil amplification functions were derived for each of six soil categories: three on crystalline basement and three on Triassic basement. Those soil amplification function distributions were used to compute soil surface hazard.

The methodology used to compute soil surface hazard is to difference the bedrock hazard disaggregation for a suite of bedrock motions and sum the probability of exceedance of surface motions using the appropriate magnitude and ground motion level-dependent soil/rock transfer functions. The approach yields soil surface hazard that would be obtained from correctly

For SRS ground motion predictions, bedrock properties underlying most of the SRS facilities are assumed uniform with a Vs of approximately 11,500 fps (3.4 km/sec). For facilities situated above the Triassic rift basin (Dunbarton basin), filled with 1.8 mi (3 km) of sedimentary rock, a Vs estimated to be 8,000 fps (2.4 km/sec) is used. This basin is surrounded by crystalline rock. For a first approximation to the ground motion effects of the basin, a one-dimensional plane-layer model is used to approximate the effect of contrasting velocities.

1.3.6.4.4 Soil Properties

SRS is located on soils (sedimentary strata) ranging in thickness from 600 to 1,500 ft (180 to 460 m) overlying crystalline or Triassic basement. A sitewide design basis spectrum must account for the range and variability in SRS soil properties. Deep stiff soils, such as those present at SRS, severely condition bedrock spectra by frequency-dependent amplification or deamplification. Depending upon the frequency and amplitude of bedrock motion, the key soil properties controlling the soil spectrum are the soil column thickness, the dynamic properties (strain dependent shear-modulus ratio and damping), low-strain soil shear-wave velocity structure, and impedance contrast with the basement. Section 1.3.5 indicates that the geology and soils present at the MFFF site are consistent with subsurface conditions found throughout SRS and F Area.

The *MOX Fuel Fabrication Facility Site Geotechnical Report* (DCS 2003) contains a detailed presentation of the site investigations that have been conducted and the results of site-specific analyses. Section 3.4 of DCS 2003 demonstrates the applicability of the SRS site generic PSHA to the MFFF site. Similarly, independent analyses by WSRC (WSRC 2003) have confirmed that the sitewide "committed" criteria are "confirmed" to be applicable to the MFFF site. Sections 5 and 6 of DCS 2003 present the MFFF site subsurface conditions and engineering properties for the MFFF site, respectively. The analysis of the site-specific subsurface conditions at the MFFF site "confirms" that they are consistent with development of SRS sitewide design spectra and that these can be used as design bases for MFFF seismic design.

To accommodate the range of shear wave-velocity in the soil column, a database of velocity profiles was compiled for SRS. This database contains the range of soil and rock shear-wave velocities available from various borings and seismic surveys that have been conducted at SRS using seismic cross-hole, down-hole, velocity logger, and refraction techniques. The shallow profiles database for SRS is based primarily on site-specific seismic piezocone penetration test soundings (SCPTU). An example of SCPTU shear-wave velocity profile is shown in Figure 1.3.6-17. Other velocity profiles consist of cross-hole and down-hole seismic surveys. The deeper soil profiles are based on measurements made in five deep boreholes drilled to basement at SRS.

Other, more numerous, deep holes are used for stratigraphic purposes and to estimate the elevation of the top of bedrock. Nearly all of the velocity data are from the SRS F, H, A, K, and L Areas, and the proposed New Production Reactor site.

Basement shear-wave velocities are estimated from compressional-wave velocities measured at SRS. These velocities were collected using seismic refraction techniques. These data show that there is a significant shear-wave velocity contrast in the SRS basement between the Dunbarton

Triassic basin rock and crystalline rock. The Pen Branch fault is the demarcation for basement contrasts in velocity.

Predicted peak soil strains for SRS are sufficient to exceed the linear range of the constitutive relations (stress-strain). Consequently, laboratory testing of site-specific soil samples was required for reliable ground motion prediction of all critical facilities.

The normalized shear modulus and damping ratio versus shear strain relationships were developed for specific stratigraphic layers. Stratigraphic formation identification and their corresponding dynamic properties were developed specifically for SRS by K.H. Stokoe of the University of Texas (Stokoe et al. 1995; Lee 1996).

Stokoe et al. compiled a dynamic soil property database from available SRS reports on dynamic soil properties and new dynamic measurements made by the University of Texas. The SRS areas from which data were obtained are as follows:

1. Area of the Pen Branch Fault Confirmatory Drilling Program
2. H-Area ITP
3. H-Area RTF
4. H-Area Building 221-H
5. Proposed New Production Reactor site
6. Par Pond Dam
7. K-Reactor Area
8. Burial Ground Expansion
9. L-Reactor Area
10. L-Area Cooling Pond Dam
11. F-Area Sand Filter Structure.

These 11 areas represent eight general locations at SRS.

Figure 1.3.6-18 illustrates the University of Texas recommended normalized mean shear modulus versus cyclic strain by formation. Figure 1.3.6-19 summarizes the hysteric damping vs cyclic shear strain by formation. These curves form the basis for the dynamic properties used in the site response analysis. Figures 1.3.6-18 and 1.3.6-19 summarize cyclic shear strain and damping for SRS.

1.3.6.4.4.1 Velocity Model Parameterization

An SRS generic shear-wave velocity profile was developed from the location-specific data and includes randomness in both stratigraphic layer thickness and velocity. Because the area-specific simulations were generally consistent with the generic simulations, the SRS generic (sitewide) simulation is applied to all areas of SRS. There is no significant reduction in the site amplification variability by applying area-specific velocity model simulations for ground motion evaluations. This SRS generic shear-wave velocity profile is appropriate for use at the MFFF site.

1.3.6.5 Current SRS Design Response Spectra

This section defines the current SRS design criteria for DOE moderate hazard (PC-3) and high hazard (PC-4) facilities.

The current DOE PC-3 and PC-4 sitewide spectra are based on *Savannah River Site Seismic Response Analysis and Design Basis Guidelines* (Lee et al. 1997) developed in 1997 and incorporate variability in soil properties and soil column thickness. Following the development of PC-3 and PC-4 design basis spectra and the PC-1 and PC-2 design basis spectra, additional conservatisms were applied to the PC-3 spectral shape at high and intermediate frequencies. The shape change was incorporated in WSRC Engineering Standard 01060 (WSRC 1999a). The shape change, illustrated in Figure 1.3.6-20, increased the low-frequency (0.1 to 0.5 Hz) portion of the PC-3 spectrum and also increased intermediate frequencies (1.6 to 13 Hz) of the design basis spectrum.

The WSRC Civil/Structural Committee reviewed the DOE PC-1 and PC-2 design spectra and recommended to the Engineering Standards Board that the current Uniform Building Code be used for the Site Engineering Standard (WSRC 1999a). The basis for the decision was that the Uniform Building Code was more conservative than the WSRC (Lee 1998) spectra.

1.3.6.6 Summary of Methodology for Development of SRS Sitewide Probabilistic Seismic Hazard Assessment (PSHA)

A disciplined, systematic approach is used to develop the PC-3 and PC-4 site-wide design spectra, and includes the contributions of national and international consultants, oversight groups and panels to validate the procedures and results. The resulting baseline data are used for selection of design bases for the MFFF.

1.3.6.6.1 General

The development of the SRS PC-3 and PC-4 seismic design spectra that form the technical basis for selecting the MFFF Design Earthquake is documented in WSRC 1997c.

The multi-discipline WSRC Site Geotechnical Services (SGS) Department, formed in 1992 to provide centralized geological, seismological, geotechnical (GSG), and geo-environmental services for SRS, uses modern, comprehensive, accurate GSG data and models. WSRC performed the work in support of the MFFF in accordance with the WSRC Quality Assurance (QA) program and Criterion 1-6 and 15-18 of ASME/NQA-1-1989. DCS has approved WSRC as a supplier of services. Section 15 of the CAR provides additional details regarding quality control and review.

"Tier 1" documentation includes the reports and its appendices prepared by WSRC's SGS in response to sitewide geoscience activities, including ground motion initiatives, and in support of critical mission facilities. For example, WSRC 1997c is an example of a report prepared in support of a sitewide initiative to develop seismic design spectra using a Probabilistic PSHA approach with a deterministic historical check. Other reports related to ground motion include WSRC 1998 and WSRC 1999d. National and international experts in geology, seismology and geotechnical engineering supported the preparation of these reports.

"Tier 2" documentation consists of the much larger body of background information maintained by SGS that comprises the analysis documentation and the results of reviews by various oversight groups and panels. These documents are prepared and checked in accordance with WSRC procedures. WSRC 2003, which demonstrates that the soil properties at the MFFF site fall within the range used to develop the SRS PC-3 and PC-4 seismic design spectra, is an example of "Tier 2" documentation. "Tier 2" documentation also includes the records of reviews by independent oversight groups and panels.

Peer reviews of past WSRC reports by industry experts have contributed through assistance and review of development of the approach used for geotechnical investigations and seismic design of structures.

In addition to reviews conducted in development of the SRS sitewide criteria, DCS also initiated a series of peer reviews of appropriate technical topics during the development of the MFFF design. The MFFF Structural Consulting Board (SCB) was formed and chartered to provide senior oversight for overall MFFF design approaches and to perform periodic reviews of in-process results. The SCB included recognized industry experts, as well as subject matter experts from within the DCS companies. SCB members have been involved in the selection of the design bases for the MFFF, and have concurred in their selection. Similarly, the MFFF Site Geotechnical Report was the subject of a detailed peer review by a panel of industry experts.

1.3.6.6.2 Comparisons with Other PSHA Studies

Section 4.0 of NUREG/CR-5250 (Bernreuter et al. 1989) compares the results of NUREG/CR-5250 with previous results from LLNL and previous studies by others. The comparisons show good agreement.

WSRC has evaluated the differences between the building code hazard assessment (National Earthquake Hazard Reduction Program - NEHRP) and the site-specific hazard evaluations used for SRS building code design (WSRC 1999d). WSRC also compared the SRS site-specific bedrock hazard with the USGS hazard, corrected to account for SRS conditions (Frankel 1999; WSRC 1999d).The USGS hazard was prepared for use in building codes, and not for use in developing seismic hazard input for nuclear facility design. Since the DOE- and NRC-accepted hazard definitions are the EPRI and LLNL hazards, WSRC has maintained the site-wide criteria developed using those hazards, and DCS has accepted those criteria as inputs for selecting the MFFF design earthquake.

1.3.6.6.3 PSHA Methodology

A PSHA incorporates the source zone definition and ground motion prediction assessments required for a deterministic approach, but also considers the estimated rates of occurrence of earthquakes, and explicitly incorporates the uncertainties in all parameters. This approach predicts the probability of exceeding a particular ground motion value at a location during a specified period of time. This approach is useful for hazard mitigation of spatially distributed facilities having different risk factors. Details of PSHA methodology is provided in WSRC 1997c and WSRC 1998. DOE STD-1023-95 (DOE 1996b) and the SRS Site-Specific PSHA are discussed below.

consistent with subsurface conditions found throughout SRS and F Area. Therefore, the SRS sitewide hazard can be used for the MFFF seismic design.

1.3.6.6.4 Results

The PC-3 and PC-4 site-wide design spectra implement DOE-STD-1023-95 (DOE 1996b), which specifies a broadened mean-based UHS representing a specified annual probability of exceedance (for a SSC performance category) and a historical earthquake deterministic spectrum that ensures breadth of the UHS. For SRS, the deterministic spectrum is represented by a repeat of the 1886 Charleston earthquake. The development of the SRS design basis spectra uses a statistical methodology to verify that a mean-based response is achieved at the soil free surface.

The EPRI and LLNL bedrock level uniform hazard spectra were averaged and broadened per DOE-STD-1023-95. Available SRS soil data were used to parameterize the soil shear-wave velocity profile. The parameterization was used to establish statistics on site response for ranges of soil column thickness present at SRS. The mean soil UHS was obtained by scaling the bedrock UHS by the ground motion dependent mean site amplification functions.

The soil data used to develop the sitewide spectra incorporate the available SRS velocity and dynamic property database available to about mid-1996. The spectra are based on soil properties and stratigraphy from specific locations at the SRS, and are parameterized to represent the variability in measured properties. Because of the potential for variation of soil properties in excess of what have been measured at the SRS, the design basis spectra are issued as a sitewide commitment for DOE facilities in accordance with the WSRC quality assurance program. Each project is required to confirm the applicability of the sitewide spectra to its project site. The soil parameters available at the specific site or facility where it is being used must be reviewed and determined to be consistent with the data parameterized in the study. The results of this review for the MFFF site are provided in the Tier 2 document WSRC 2003. As discussed in Sections 1.3.5 and 1.3.6.4.4 of the CAR, the analysis of the site-specific subsurface conditions at the MFFF site indicates that the geology and soils present at the MFFF site are consistent with subsurface conditions found throughout SRS and F Area. Therefore, the SRS sitewide hazard can be used for the MFFF seismic design.

The current PC-3 and PC-4 sitewide spectra are based on the WSRC analysis developed in 1997 and incorporate variability in soil properties and soil column thickness. The design basis spectra for PC-3 and PC-4 are given in Figure 1.3.6-13 and Figure 1.3.6-14, respectively. After the development of PC-3 and PC-4 design basis spectra and the PC-1 and PC-2 design basis spectra, additional conservatisms were applied to the PC-3 spectral shape at high and intermediate frequencies, and the shape change was incorporated in the Site Engineering Standard (WSRC 1999a). The shape change, illustrated in Figure 1.3.6-20, increased the low-frequency (0.1-0.5 Hz) portion of the PC-3 spectrum and also increased intermediate frequencies (1.6-13 Hz) of the design basis spectrum.

1.3.6.7 Definition of the MFFF Design Earthquake

Previous sections have presented the basis for establishing seismic criteria for DOE PC-3 and PC-4 SSCs at SRS. Soil surface hazard relationships (acceleration versus mean annual probability of exceedance) presented in WSRC 1998 are used to evaluate the relative probability of exceedance of the PC-3 and PC-4 accelerations and the accelerations of intermediate spectra. Figure 1.3.6-20 shows the current PC-3 ground surface spectrum at 5% damping, while Figure 1.3.6-14 shows the current PC-4 ground surface spectrum. The MFFF-specific geotechnical data are consistent with the SRS-specific data used to develop the PC-3 and PC-4 design spectra. The application of the PC-3 and PC-4 design spectra is confirmed to be appropriate for the MFFF site in accordance with WSRC 1997c. Therefore, based on the site-specific MFFF geotechnical data (DCS 2003), the SRS PC-3 and PC-4 design spectra are also MFFF site-specific. The PC-3 and PC-4 design spectra are conservative spectra with probabilities of exceedance of 5×10^{-4}/yr and 1×10^{-4}/yr, respectively, based on evaluation of SRS-specific soil surface hazard curves (WSRC 1997c; WSRC 1998). Because the PC-3 design spectrum is also MFFF site-specific, it has a consistent probability of exceedance (5×10^{-4}/yr) at each oscillator frequency and envelopes the 5×10^{-4}/yr uniform hazard spectrum.

Using the acceleration hazard relationships shown in Figure 1.3.6-24 for each of the four oscillator frequencies (1 Hz, 2.5 Hz, 5 Hz, and 10 Hz) represented in the hazard chart, the spectral acceleration can be read off each of the 5% damped response spectra (Figure 1.3.6-20 for PC-3, Figure 1.3.6-14 for PC-4, and Figure 1.3.6-21 for Regulatory Guide 1.60). These spectral accelerations are used to enter Figure 1.3.6-24 and to read the associated annual mean probability of exceedance. Inverting the annual mean probability of exceedance results in the return period shown in Table 1.3.6-7. These surface accelerations represent approximately 2,700-year and 22,000-year surface accelerations at 5 Hz for the PC-3 and PC-4 spectra, respectively.

To achieve safety performance goals (i.e., to ensure that high consequence events are highly unlikely), conservative design criteria between these two spectra are selected for the MFFF. Figure 1.3.6-21 compares a Regulatory Guide 1.60 5% spectrum scaled to a PGA of 0.20g to the surface spectra for PC-3 and PC-4 facilities. It can be seen that the Regulatory Guide 1.60 spectrum significantly envelops the PC-3 spectrum in frequency ranges of significant structural interest. The return period of representative acceleration ordinates can be determined in the same way as it was for PC-3 and PC-4 above (Table 1.3.6-7). The 0.2g Regulatory Guide 1.60 spectrum envelopes the PC-3 spectrum, and therefore, has even lower probabilities of exceedance than the PC-3 spectrum. Figure 1.3.6-23 compares the 0.2g Regulatory Guide 1.60 spectrum to the soil surface uniform hazard spectrum at four frequencies (1, 2.5, 5 and 10 Hz). It can be seen that at a frequency of 1 Hz, the spectral acceleration for the MFFF design spectrum is less than the 10,000-year UHS. For frequencies of practical structural interest, 2.5, 5 and 10 Hz, the spectral acceleration ordinates for the 0.2g Regulatory Guide 1.60 soil surface design earthquake are greater than the 10,000-year UHS. Appendix C of DOE 1994 presents an evaluation that shows that a median annual probability of exceedance of 10^{-5} corresponds approximately to a mean annual probability of exceedance of 10^{-4}. By selecting accelerations consistent with a (10,000-year) 10^{-4}/yr mean annual probability of exceedance, this spectrum meets the intent of Regulatory Guide 1.165, which suggests a 10^{-5}/yr median annual probability of exceedance.

On this basis, a 0.2g Regulatory Guide 1.60 horizontal spectrum is selected as the soil surface design earthquake spectrum for design of MFFF buildings and structures. For evaluation of subsurface conditions, to include liquefaction and dynamic settlements, bedrock motions based on the SRS PC-3 bedrock spectrum will be used, scaled so that when amplified through the site soil profile, the resulting surface ground motion will have 0.20g PGA.

Initial evaluations of SRS earthquake hazards for the MFFF did not indicate that near-field (closer than 9.3 mi [15 km]) earthquakes would be dominant. WSRC-TR-99-00271, *Computation of USGS Soil UHS and Comparison to NEHRP and PC-1 Response Spectra for the SRS* (WSRC 1999d), indicated that although the near-field earthquakes are not dominant, their contribution is potentially significant. WSRC-TR-2001-00342, *Development of MFFF-Specific Vertical-to-Horizontal Seismic Spectral Ratios* (WSRC 2001) indicated that the vertical component would be greater than the initially selected 2/3 ratio.

ASCE 4-98 recommends that if near-field earthquakes are dominant, the ratio of vertical to horizontal spectral ordinates be taken as, at least, unity for frequencies above 5 Hz, 2/3 for frequencies below 3 Hz, and a transition between 3 Hz and 5 Hz. This is closely and conservatively approximated by the Regulatory Guide 1.60 vertical spectrum scaled to the same 0.2g PGA. Therefore, for the MFFF, the vertical component of earthquake motion at the soil surface will be selected as the Regulatory Guide 1.60 vertical spectrum scaled to 0.2g PGA. This results in vertical and horizontal spectra that are consistent with the guidance in ASCE 4-98 and Regulatory Guide 1.60, and appropriately consider the effects of near-field earthquakes. Figure 1.3.6-22 illustrates the selected design earthquake response spectrum.

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1.3.7 Stability of Subsurface Materials

Subsurface geologic and soil conditions at the MFFF site are detailed in Section 1.3.5, and comments are given there on how those site conditions will affect the soil stability.

As discussed in Section 1.3.5, the initial spacing of cone penetrometer test (CPT) exploration holes for the MFFF site was based on the approximate spacing patterns that were found to be successful in identifying potential soft zones at the nearby Actinide Packaging and Storage Facility (APSF) project site. The same process that was used successfully at the end of the APSF exploration program was used as the initial exploration hole spacing to identify potential soft zones on the MFFF site. When soft zones were encountered, additional CPT and exploration holes were added to delineate the extent of soft zones found. The resulting close spacing of exploration holes is also sufficient to identify loose soil zones that may be present at locations of MFFF principal SSCs, such as the MOX Fuel Fabrication Building and Emergency Generator Building.

The MOX Fuel Fabrication Building and Emergency Generator Building were relocated to the western portion of the MFFF site when significant soft zones were encountered at the initial building locations. The same process used for initial layout of the CPT and exploration hole spacing was used for additional exploration in the western area of the MFFF site. In addition to the CPT holes and exploration borings made for the MFFF site, several exploration borings from previous exploration programs in the area were used for evaluation of subsurface conditions at the new building locations. The new CPT and exploration boring spacing, in conjunction with previous exploration holes, provided an exploration hole spacing closer than was deemed necessary for the initial facility layout.

The approach for the layout of CPTs and exploration borings at the MFFF site provides confidence that soft and loose soil zones have been effectively identified in the vicinity of the MFFF principal SSCs. Conservative assessments are presently being used to define identified soft zones and loose soil zones in the vicinity of the MFFF principal SSCs. Exploration spacing in the original geotechnical investigation was greater than desired because the drilling and CPT rigs could not access locations on the existing APSF spoils pile berm slopes. After grading of the slopes facilitated rig access for additional exploration hole locations, DCS conducted a supplemental geotechnical investigation to acquire additional subsurface information to provide increased confidence that the size and extent of soft zones beneath the MFFF principal SSCs are adequately characterized. The results of these supplemental investigations are consistent with the results obtained during the initial site investigations, and they are described in detail in *MOX Fuel Fabrication Facility Site Geotechnical Report* (DCS 2003).

General geotechnical stability concerns are categorized and listed below with the intent of defining the approaches and methods used to address stability of subsurface materials. Geotechnical stability concerns at the MFFF site fall into the following two categories:

- Liquefaction (Section 1.3.7.1)
- Soft zones (Section 1.3.7.2).

1.3.7.1 Liquefaction Susceptibility

The liquefaction susceptibility of loose subsurface materials at the MFFF site will be evaluated using qualitative and quantitative approaches. Site-specific investigations have been conducted for the MFFF site, as discussed in Section 1.3.5. Approaches implemented will include criteria for clayey soils, shear wave velocity evaluation, the stress method, and the strain method. Field programs have been conducted and laboratory testing is being performed to characterize site conditions and to define behavior characteristics of the native MFFF site soils. Section 1.3.5 addresses the MOX site soil profile and characteristics. The groundwater level at the time of the exploration programs was measured at an elevation of approximately 205 ft (62.5 m) above msl, which is more than 60 ft (18.3 m) below the planned site grade. The MFFF site exploration programs have identified only a few isolated pockets of loose soils at depth, below the groundwater table.

On 30 June 2003, DCS submitted the *MOX Fuel Fabrication Facility Site Geotechnical Report* (DCS 2003) for NRC review. This report contains a detailed presentation of the site investigations that have been conducted and site-specific analyses, including liquefaction analyses. Section 8 of this document demonstrates the acceptability of the MFFF site with respect to liquefaction and post-earthquake dynamic settlement. This section of the report also demonstrates that the 1886 Charleston earthquake control motion is the controlling earthquake motion for liquefaction and post-earthquake dynamic settlement for the MFFF site. The results of the analyses indicate that any areas of potential liquefaction are at depth and exist as isolated pockets that are confined by strong non-liquefiable soils. The analyses also indicate that post-earthquake dynamic settlements are not excessive and considered acceptable for the design of principal SSCs.

1.3.7.2 Evaluation of Soft Zones

Across SRS, the soil zone between approximately 100 and 250 ft (30.5 and 76.2 m) below ground surface is a marine deposit labeled the Santee Formation. Within this interval are areas with locally high concentrations of calcium carbonate. Often found within these sediments, particularly in the upper third of this section, are weak zones interspersed in stronger matrix materials. These weak zones, which vary in thickness and lateral extent, are termed "soft zones." The existence of soft zones and the potential for settlement are site-specific characteristics and require subsurface characterization and engineering evaluation on a site-specific basis.

At the MFFF site, the Santee Formation is generally found below an elevation of 180 ft (54.9 m) above msl, which is more than 90 ft (27.4 m) below the planned site grade. The soft zones found at the MFFF site are consistent with soft zones identified in the adjacent APSF and F-Area geotechnical programs. The exploration programs indicated that soft zones at the MFFF site are isolated and found as soft soil pockets at depth. The field exploration program used close exploration hole spacing to identify and locate soft zones and to delineate their approximate boundaries, when encountered near planned structure locations. MFFF principal SSCs, such as the MOX Fuel Fabrication Building and Emergency Generator Building, were located on the MFFF site to avoid placement directly over significant soft zones identified during site explorations. The SSC locations were determined in accordance with detailed site-specific geotechnical analysis (DCS 2003), which also demonstrates the acceptability of the soft zones identified at the MFFF site.

The soft zones at SRS and at the MFFF site are stable under static conditions. The Santee Formation, in which the carbonate and soft zones are found, is generally in the saturated zone well below the water table. Here the sediments are in a stable chemical environment, and carbonate dissolution is minimal. Further dissolution and removal of the Santee carbonate is not a concern in the time frame of interest for the MFFF (i.e., 50-100 years). The geologic record at SRS shows that soft zones encountered today have withstood the earthquakes that have occurred since their formation. No subsidence under static or seismic conditions is expected from the soft zones identified at the MFFF site.

For the types of facilities to be constructed at the MFFF site, the increase in load on the soft zone soils is considered to be moderate to negligible. Potential load increases due to static and seismic design loads and deformations that may result in the soft zones from static or dynamic foundation loading were evaluated using appropriate geotechnical methods. Structure settlement that may result from deformation of any soft zones beneath or adjacent to critical structures has been defined (DCS 2003). MFFF principal SSCs will be designed to accommodate anticipated settlement from soft zones, if required.

1.3.7.3 Slope Instability Hazard Evaluation

The preliminary site contour map (Figure 1.3.7-1) defines the original topography, proposed finish grades, location of major cut and fill slopes, and location of the principal SSCs. The nearest cut slopes will be over 400 ft (121.9 m) both north and west from the BMF and are only approximately 15 ft (4.6 m) high. The BMF and the BEG will be located with finished floor elevations below the existing ground elevation, and are both over 400 ft (121.9 m) from the top of the nearest fill slope or steeper topographic slope. Figure 1.3.7-1 shows the fill and steep slopes to the northwest, northeast, and southeast of the BMF and BEG. Therefore, slope stability from existing topography and planned fills and cuts at the MFFF site will not have any adverse impact to principal SSCs.

1.3.7.4 Actinide Packaging and Storage Facility Spoil Evaluation

The preliminary site contour map shown in Figure 1.3.7-1 shows the location of the spoil pile created from the excavated materials removed from the APSF. During MFFF site grading, this APSF spoil pile will be removed and will not be used in connection with foundations for the principal SSCs. Therefore, the pile cannot adversely impact principal SSCs.

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1.3.8 References

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4. ORGANIZATION AND ADMINISTRATION

The Duke Cogema Stone & Webster (DCS) functional organizational structure is shown in Figure 4-1 for the design and construction phases of the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) portion of the MOX Fuel Project.

The discussion herein will be updated in the license application for possession and use of special nuclear material (SNM) as appropriate to incorporate changes that may be necessary to reflect the following:

- Identification and functional description of the specific organizational groups responsible for operating the MFFF
- Authorities, responsibilities, and lines of communication among the operations organizational groups
- Operations organizational charts that depict the lines of responsibility and authority and the key management positions.

4.1 ORGANIZATIONAL STRUCTURE AND KEY MANAGEMENT POSITIONS DURING DESIGN AND CONSTRUCTION

The DCS functional organization structure indicates the lines of communication and control of activities associated with the design and construction of the MFFF. The reporting structure, along with functional responsibilities and levels of authority, for the various organizational entities is described below in the position descriptions for the MFFF design and construction phases of the project. Qualification requirements for these key management positions are also provided. Relevant work experience of at least five years, in addition to the minimum experience requirements specified below, may be substituted for educational Bachelors degree (or equivalent) requirements. Where work experience in more than one field is required for a given position (e.g., four years of engineering experience and two years of management experience), the experience may be concurrent unless otherwise indicated.

Stop-work authority within DCS is vested in each DCS employee, with respect to work within their scope of responsibility, whenever health and safety issues are involved. Following a stop-work, activities related to safety are controlled until the deficiency, or unsatisfactory condition, has been resolved. Responsible managers have the authority to delegate tasks to other individuals; however, the responsible manager retains the ultimate responsibility and accountability for implementing the applicable requirements.

The positions described below are DCS management personnel with responsibilities for the principal structures, systems, and components (SSCs) and related activities. DCS will establish management measures as necessary and appropriate to ensure availability and reliability of principal SSCs. These personnel are appropriately available to perform their duties during MFFF design and construction.

4.1.1 Office of the President

The President is responsible for project management of all DCS MOX Fuel Project activities, including those related to safety, and as such has the ultimate responsibility for the principal SSCs during MFFF design and construction. The President is the Chief Operating Officer of DCS. The Quality Assurance (QA) Manager reports directly to the President.

The Office of the President also includes senior management representatives (e.g., functional area Vice Presidents) responsible for implementing the direction of the President and integrating the functional areas discussed in the sections below. Other functional managers report to the President either directly or through these senior management representatives.

The minimum qualifications for the President are a Bachelors degree (or equivalent) in engineering or science, five years of experience in operations and/or engineering of nuclear facilities, and five years of experience in management. The minimum qualifications for senior management representatives are a Bachelors degree (or equivalent), four years of management experience, and two years of nuclear industry experience.

4.1.2 QA Manager

The QA Manager reports directly to the President and is responsible for establishing and maintaining the DCS MOX Project QA Plan. This position is independent of the managers responsible for performing quality-affecting work and is independent of cost and schedule considerations.

The QA Manager may be assigned other duties; however, none of these duties is allowed to compromise the independence of this function or to prevent needed attention to QA matters. The QA Manager has the same access to the President as the line managers of the various functional areas of the project. This position is able to identify quality problems; initiate, recommend, or provide solutions; verify implementation of solutions; and ensure that further processing, delivery, installation, or use is controlled until proper disposition of a nonconformance, deficiency, or unsatisfactory condition has occurred.

The QA Manager has the responsibility for approval of the subcontractor QA programs and oversight and audit functions during MFFF construction. The site assigned QA personnel will provide daily oversight of construction activities and will perform audits of the construction management organization and the subcontractors. Each construction subcontractor will have a defined scope of work, contract terms and conditions specifying the QA/QC requirements and technical specifications and drawings, which specify the quality and technical requirements of the scope of work. Each subcontractor is required to perform the QA audits and QC inspections required by their DCS approved QA program. The Construction Management Organization is responsible for management of the subcontract and the QA Manager assures that the subcontractor conforms to the quality program approved for the subcontract work scope by providing oversight witness of final testing and audits of selected test activities.

The minimum qualifications for this position are a Bachelors degree (or equivalent), four years of QA-related experience, two years of nuclear industry experience, and one year of supervisory or management experience.

- performance requirements of 10 CFR §70.61. This task is accomplished through the preparation of a likelihood analysis, criticality analysis, shielding analysis, structural analysis, fire hazard analysis (FHA), and other specific evaluations.
- Identify specific operating requirements.

During the operation phase, the ISA is used to evaluate changes to facility design or operations to ensure that they satisfy the requirements of 10 CFR §70.72.

The focus of the ISA and SA is on the identification of IROFS (principal SSCs in the SA). The identified IROFS are the necessary and sufficient set of design features and administrative controls to be implemented in the final design to satisfy the performance requirements of 10 CFR §70.61. To provide an additional safety margin and satisfy the requirements of 10 CFR §70.64(b), the MFFF employs defense-in-depth practices. These features ensure that multiple layers of risk reduction exist. The principal SSC and defense-in-depth designations are made on an event/receptor basis. An SSC designated as a principal SSC to protect the facility worker for any given event may also be designated as a defense-in-depth feature to protect the site worker and an individual outside the controlled area (IOC), for the same event (definition for dose receptors are found in Section 5.4.4). SSCs designated as defense-in-depth are also principal SSCs (and fall under the 10 CFR 50 App B, NQA-1 QA program), but are not required or credited in the analysis for the event/receptor to meet the performance criteria of 10 CFR §70.61.

The MFFF also incorporates additional protection features into the facility design and operation. These features provide additional protection by reducing the challenges to the IROFS and defense-in-depth features.

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5.4 SAFETY ASSESSMENT OF DESIGN BASIS METHODOLOGY

The SA is the first step in the development of the ISA. To accomplish the SA objective as described in Section 5.0, a hazard assessment and a preliminary accident analysis are performed. Hazard assessment includes the identification of specific hazards and the evaluation of those hazards through the development of event scenarios. Accident analysis consists of further analyzing events identified in the hazard assessment, establishing the principal SSCs (including administrative controls and their associated design basis), and providing a basis for the selection of those SSCs.

Figure 5.4-1 provides a flow diagram of the ISA process. As shown, the ISA consists of two parts: (1) the SA documented in this submittal, and (2) the latter phase of the ISA to be submitted as part of the license application for possession and use of special nuclear material (SNM).

The first step of the SA is to identify the hazards applicable to the MFFF. The identification of hazards is based on the MFFF preliminary design (Chapter 11). Hazards related to natural phenomena and external man-made events are identified based on the site description of the MFFF (Chapter 1). For fire-related hazards, a Fire Hazards Analysis (FHA), described in Section 7.4, is performed. The FHA is part of the ISA. At this stage of the MFFF design, a Preliminary Fire Hazards Analysis is performed in order to identify the specific fire hazards and to propose fire protection features that will function as principal SSCs in order to limit the consequences from fire events. The process by which the hazards have been identified is described in Section 5.4.1, and the resulting identified hazards are listed in Section 5.5.1. Within this identification process, NPHs established to be not credible, as defined in Section 5.4.3, are screened and removed from further consideration.

After the applicable hazards have been identified, a hazard evaluation is performed to develop event scenarios. Hazard evaluation is the process of linking hazards, identified during the hazard identification process, with postulated causes to produce event scenarios. The process by which this evaluation is performed is described in Section 5.4.1.2. These events are then characterized as event types, which are described in Section 5.4.1.2.1.

Once the event types have been established, a preliminary accident analysis is performed to assess the unmitigated consequences to the facility worker, site worker, the IOC, and the environment. For the site worker, the IOC, and the environment, conservative quantitative consequences are established. For the facility worker, conservative qualitative consequences are estimated. The process of evaluating these consequences is detailed in Section 5.4.4.

Events with unmitigated consequences that are less than "intermediate" (defined as "low" in this analysis), as defined by 10 CFR §70.61, are screened and do not require further evaluation. These events are discussed in Section 5.5.2.11. A safety strategy is then established for the remaining events. Section 5.4.2 describes the process by which the safety strategy is established, and Section 5.5.2 presents the implemented safety strategies by event type. Note that within the safety strategy (Section 5.4.2.3), events with common safety strategies, and hence common principal SSCs, are grouped together into event groups, thereby reducing the amount of repetition in the discussion of the safety strategy. For fire-related events, a fire safety strategy is formulated for each respective fire area of the facility. This fire safety strategy is based on a consequence analysis for each of the respective fire areas and an assessment of the feasibility of implementing the selected fire safety strategy.

From the established safety strategies, principal SSCs (including administrative controls) required to implement the safety strategy are specified. For the SA, specification of these principal SSCs is limited to structure- and system-level items (component-level items will be specified in a latter phase of the ISA) and administrative controls. For each of the specified structures and systems, the design bases are determined, as well as the potential support functions required to ensure the effectiveness/availability of these items during the hypothesized (analyzed) event. The process by which these items are identified and evaluated is described in Section 5.4.2.

The final step performed in the SA is to establish the mitigated consequences for the bounding event for each event type. Section 5.4.4 presents the methodology used to establish these consequences, and Section 5.5.3 presents the results. These mitigated consequences are used to establish performance requirements for the principal SSCs to ensure that the performance requirements of 10 CFR §70.61 are satisfied. Section 5.4.5 describes the "Latter Phase of the ISA" portion of Figure 5.4-1.

5.4.1 Hazard Assessment Methodology

The purpose of the hazard assessment is to identify and evaluate hazards associated with the MFFF. Accordingly, hazard assessment is comprised of two tasks: hazard identification (Section 5.4.1.1) and hazard evaluation (Section 5.4.1.2). Hazard assessment provides the basis for identifying events and determining risk.

The MFFF hazard assessment was performed in accordance with guidance provided in Draft NUREG-1513, *Integrated Safety Analysis Guidance Document* (U.S. Nuclear Regulatory Commission [NRC] 1999), and *Guidelines for Hazard Evaluation Procedures* (AIChe 1992). The hazard assessment methodology was selected based on the guidance provided in NUREG-1513 to perform the hazard assessment of the MFFF because it is well suited to the preliminary phase of the MFFF design.

5.4.1.1 Hazard Identification

Hazard identification is the process of identifying hazards that could impact MFFF operations. To facilitate the hazard identification process, the MFFF was divided into workshops and further subdivided into process units within each workshop. This segmentation of the facility allows the analyst to focus on a specific section of the overall process and ensures a thorough and comprehensive hazard identification. The grouping of process units by workshop is presented in Section 5.5.1, and the process units are described in Chapter 11.

Utilizing these workshops, radioactive and hazardous material associated with MFFF operations, hazardous energy sources associated with MFFF operations, NPHs that could impact MFFF operations, and EMMHs that could impact MFFF operations were identified. Each of these constituent elements of the hazard identification process is described in the following sections.

- **Criticality** – The attainment of a self-sustaining fission chain reaction potentially resulting in the release of a large amount of energy over a short time period.
- **Natural Phenomena** – Initiating events caused by NPHs.
- **External Man-Made Events** – Initiating events caused by EMMHs.
- **External Exposure** – Events producing a direct radiation dose from radiation sources external to the body.
- **Chemical Release** – Events that result in a pure chemical release that may affect nuclear safety, a chemical release of a chemical produced from licensed material, or a chemical release in conjunction with a radiological release.

5.4.1.2.2 Unmitigated Event Description

The unmitigated event description provides information concerning the event scenario, including the hazardous material involved in the scenario, operating mode of the affected process units, specific process unit or location, causes, and major effects of the event. The unmitigated event description does not credit or describe SSCs that prevent or mitigate the event. The event description provides the basis for assessing unmitigated event likelihood, consequence, and risk.

To avoid repetition, events common to process units within a workshop are presented as one event. Events applicable to a specific process unit are presented separately. For example, a leak from a glovebox through a seal is presented once for all gloveboxes, but an oxygen-fed fire is presented for the calcining furnace only since it is the only process unit connected to the oxygen supply system.

5.4.1.2.3 Postulated Causes

Causes are the means by which hazards create postulated events. Therefore, a single cause in conjunction with an identified hazard is a necessary and sufficient condition to create an event. The major causes for each postulated event are identified. Causes are based on the level of design information available and can be specific or general. The general class of causes identified includes mechanical or electrical failure of equipment, human errors, NPHs, or EMMHs.

It should be noted that all causes are not required or identified in the hazard assessment. At this juncture, the objective of the analysis is to simply determine the feasibility of events in given locations.

5.4.1.2.4 Unmitigated Likelihood Estimate

During the SA, the likelihood of all events generated by internal hazards was conservatively assumed to be Not Unlikely as defined in Section 5.4.3. Consequently, no internal event was screened due to likelihood considerations. The event initiator is assumed to occur for all events (excluding natural phenomena events exceeding the design basis events).

5.4.1.2.5 Unmitigated Consequence Estimate

The unmitigated consequence assessment to the IOC, site worker, facility worker, and environment is based on conservative estimates for the material at risk, release fractions, and dispersion factors. Application of conservative estimates for each of these factors ensures a large margin in the reported consequences. Section 5.4.4 and Chapter 8 present the methodology for calculating radiological and chemical consequences, respectively.

The consequence severity levels that are used in the hazard evaluation are based on 10 CFR §70.61 and are provided in Table 5.4-1.

5.4.1.2.6 Unmitigated Risk Designation

Risk is the product of the event likelihood and consequence. Table 5.4-2 identifies when principal SSCs are applied, as a function of the unmitigated event risk, to satisfy the performance requirements of 10 CFR §70.61.

5.4.2 Preliminary Accident Analysis Methodology

The major purpose of the preliminary accident analysis is to identify principal SSCs and their associated design bases. A secondary purpose is to provide bounding consequence calculations as necessary. These purposes are accomplished by performing further analysis of all events identified in the hazard assessment. The analysis consists of the following major steps:

- Event screening
- Identification of event groups
- Development of safety strategy
- Selection of principal SSCs
- Design bases of principal SSCs
- Support functions related to principal SSCs
- Bounding mitigated consequence analysis.

The analysis is an iterative process involving these steps until the preferred acceptable solution is reached. Thus, these steps are not necessarily performed in a step-by-step manner for all events. Each of these respective steps in the preliminary accident analysis is described in the following sections. In addition, it is important to recognize that during the preliminary accident analysis, the multi-disciplinary team evaluates safety alternatives to ensure that competing risks are adequately addressed. In this manner, the multi-disciplinary team arrives at a final safety strategy that will ensure that events satisfy the performance requirements of 10 CFR §70.61. Thus, the ISA process ensures that the proposed means to address a given event are compatible with the safety strategies formulated to address all other events.

5.4.2.1 Event Screening

Events whose consequences have been determined to be low require no further evaluation and are screened. Justification for the screening of events is provided in Section 5.5.2.11. The

- Analysis of failure modes and common mode failures
- Special inspection, testing, and maintenance requirements
- Management measures applied to the item and the basis for grading
- Safety parameters controlled by the item, safety limit on the parameter
- Assessment of the impact of non-safety features on IROFS ability to perform their function.

These analyses will be applied to each event sequence with the potential to exceed 10 CFR §70.61 requirements. The analyses verify that single failure criterion or double contingency principle is effectively applied, that there are no common mode failures, that the IROFS will be effective in performing their intended safety function, that the conditions that the IROFS will be subjected to will not diminish the reliability of the IROFS, and also identify and verify appropriate IROFS failure detection methods. Each of the event sequences and the accompanying specific measures provided by the aforementioned deterministic criteria will be documented in the ISA and summarized in the ISA summary. This combination of analyses will demonstrate that the likelihood requirements of 10CFR70.61 are satisfied.

In conjunction with (but separate from) the safety/licensing basis to provide additional confidence in the demonstration of the adequacy of these deterministic design criteria, a supplemental likelihood assessment will be conducted for events (excluding NPH events) that could result in consequences that exceed the threshold criteria for the site worker or the IOC. This supplemental assessment will be based on the guidance provided in NUREG 1718 and will demonstrate a target likelihood comparable to a "score" or -5 as defined in Appendix A of NUREG 1718.

5.4.4 Methodology for Assessing Radiological Consequences

The methodology for assessing radiological consequences for events releasing radioactive materials is based on guidance provided in NUREG/CR-6410, *Nuclear Fuel Cycle Facility Accident Analysis Handbook* (NRC 1998b). The methodology for evaluating the consequences of a criticality event is described in Section 5.5.3.4. In this section, the methodology used to calculate radiological consequences is provided for the unmitigated and mitigated cases. Unmitigated results established from the application of this methodology are used to establish a safety strategy. Mitigated results established from the application of this methodology are presented in Section 5.5.3.

The radiological consequences for the MFFF facility worker (facility worker), site worker, the individual located outside of the controlled area boundary (IOC), and the environment are assessed for events identified in the hazard evaluation. A facility worker is considered to be within the MFFF located inside a room near a potential accident release point. The site worker is considered to be 328 ft (100 m) from the MFFF building stack. The IOC is defined as the maximally exposed individual outside the controlled area boundary. The controlled area boundary is approximately 525 ft (160 m) from the MFFF building stack.

The MFFF restricted area is coincident with the protected area, an area encompassed by physical barriers and to which access is controlled and is located at 171 ft (52 m) from the MFFF building stack. Radiological consequences to the environment are assessed outside the MFFF restricted area (i.e., at the restricted area boundary).

Radiological releases are modeled as instantaneous releases to the facility worker and are conservatively modeled for the site worker and the IOC using a 0- to 2-hour 95th percentile dispersion χ/Q. Radiological releases to the environment are modeled by converting an instantaneous release into an equivalent release averaged over 24 hours and then multiplying by the 24-hour average dispersion χ/Q at the restricted area Boundary. No evacuation is credited for the assessment of the unmitigated radiological consequences.

5.4.4.1 Quantitative Unmitigated Consequence Analysis to Site Worker and the IOC

For each identified event sequence in the hazard evaluation, a bounding consequence for that event sequence is calculated. The bounding consequence is established by determining the applicable locations and locating the specific materials at risk from Tables 5.5-3a and 5.5-3b. The applicable, bounding material-at-risk values are then established from the identified values by selecting the maximum value for each form and each compound. Values for each form and compound are conservatively selected due to the dependence of the airborne release fraction, the respirable fraction, the specific activity, and the dose conversion factors.

5.4.4.1.1 Source Term Evaluation

The first step in the evaluation of the unmitigated consequences is to determine the source term. The source term is determined based on the five-factor formula as described in NUREG/CR-6410 (NRC 1998b). The five-factor formula consists of the following parameters:

- MAR – Material At Risk, kg
- DR – Damage Ratio, unitless
- ARF – Airborne Release Fraction, unitless
- RF – Respirable Fraction, unitless
- LPF – Leak Path Factor, unitless.

These parameters are multiplied together to produce a source term (ST) representative of the amount of airborne respirable hazardous material released per a bounding scenario, as follows:

$$[ST]=[MAR]\times[DR]\times[ARF]\times[RF]\times[LPF] \qquad (5.4\text{-}1)$$

Applicable, bounding quantities are established for each of these factors. Note that for entrainment events, the airborne release fraction is replaced with the airborne release rate (ARR) multiplied by the entrainment duration (i.e., ARF = ARR x duration). It has been assumed that the duration of the entrainment release is one hour, assuming no evacuation. The unmitigated consequences associated with entrainment events are orders of magnitude below those associated with the bounding events. A longer duration of release up to the entire MAR involved in the event would not impact the safety strategy and the mitigated consequences would still be acceptable.

The LPF in all unmitigated cases is conservatively assumed to be one (i.e., no credit is taken for leak paths). A discussion crediting LPFs in mitigated radiological consequence evaluations is provided in Section 5.4.4.4.

Applicable ARF and RF values are established for the material forms (i.e., powder, solution, pellet, rod, and filter), the material types available at the MFFF, and the release mechanisms that could potentially occur at the MFFF from values presented in NUREG/CR-6410 and DOE-HDBK-3010, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE 1994). Bounding ARF and RF values are then established for each material form per release mechanism by maximizing the product of these two factors of the potential material types found at the MFFF (i.e., maximizing ARF x RF for each form and per release mechanism). Thus, the result is applicable bounding ARF and RF values for specific release mechanisms for specific material forms.

For some events identified in the hazard evaluation, the identified event may encompass a number of release mechanisms. In these cases, the bounding product of the ARF and RF, per material form, will be applied to the MAR. The bounding products considered are based on the entrainment, explosive detonation, explosive overpressurization, fire/boil, and drop/crush release mechanisms for materials of a specific form.

A DR of one (1.0) is conservatively utilized to determine the radiological consequences for most material forms and events. Exceptions include fuel rods and pellets for an explosive over-pressurization event, fires in select storage areas, and the drop of multiple fuel assemblies.

5.4.4.1.2 Dose Evaluation

The source term is used to calculate the total effective dose equivalent (TEDE). TEDE values are calculated for exposure via the inhalation pathway to a site worker (S) and the IOC. Other potential pathways (e.g., submersion and ingestion) are not considered to contribute a significant fraction to the calculated TEDE. The following expression is used to calculate the TEDE for potential radiological releases at the MFFF:

$$[\mathrm{TEDE}]_{S,IOC} = [\mathrm{ST}] \times [\chi / Q]_{S,IOC} \times [\mathrm{BR}] \times [\mathrm{C}] \times \sum_{X=1}^{N} [f]_X \times [\mathrm{DCF}]_{effective,X} \qquad (5.4\text{-}2)$$

where:

ST = source term unique to each event, kg

$[\chi/Q]_{S,IOC}^{S,P}$ = atmospheric dispersion factor unique to the site worker and the IOC, sec/m^3

BR = breathing rate, m^3/sec

C = unit's conversion constant, unitless

f_x = includes the specific activity and the fraction of the total quantity of the MAR that is the radionuclide X, Ci_x/kg

$DCF_{effective,X}$ = effective inhalation dose conversion factor for the specified radionuclide X, rem/Ci

N = total number of inhalation dose-contributing radionuclides involved in the evaluated event, unitless.

Table 5.4-3 lists the radionuclide composition of common materials located in the MFFF that have been evaluated for potential release in the hypothesized accident events.

Atmospheric dispersion factors (χ/Q) for the site worker and the IOC were established from SRS data using the ARCON96 computer code. This code is briefly discussed in Section 5.4.4.1.3.

The breathing rate (BR) is conservatively assumed to be 3.47×10^{-4} m^3/sec (20.8 L/min). This value is from Regulatory Guide 1.25 (NRC 1972) and is equivalent to the uptake volume (10 m^3) of a worker in an 8-hour workday.

The inhalation dose conversion factors (DCFs) are taken from Federal Guidance Report No. 11 (EPA 1989), based on the form of the potential releases from the MFFF when received by the dose receptor. For the MFFF, dose receptors are conservatively assumed exposed to oxides of unpolished plutonium, polished plutonium, and/or uranium, and/or elemental americium. The oxides have specific activities (molecular) that are greater by a factor of 2 than those of other potential release forms (e.g., plutonium oxalates and nitrates). For many radionuclides, Federal Guidance Report No. 11 provides dose conversion factors for more than one chemical form (or solubility). The multiple forms are represented by transportability classes. For the MFFF, Y class DCFs have been used for all radionuclides except americium, which only has a W class DCF. Releases of soluble materials are bounded by those of the insoluble form because the amount of MAR in the bounding events for soluble releases is smaller than the amount of MAR for the insoluble releases.

Once unmitigated radiological consequences are established for each event identified in the hazard assessment, events are grouped and bounding events are established for each of these groupings under each event type. Unmitigated radiological consequences established for each bounding event are then compared to the limits in Table 5.4-1. Based on this comparison and potential prevention and/or mitigation features available to each event grouping, the safety strategy is established for each bounding event within an event type.

5.4.4.1.3 Atmospheric Dispersion Evaluation

5.4.4.1.3.1 MACCS2

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5.4.4.1.3.2 ARCON96

The ARCON96 computer code was used to compute the downwind relative air concentrations (χ/Q) for the site worker located within 328 ft (100 m) of a ground-level release from the MFFF to account for low wind meander and building wake effects and for the IOC located at 525 ft (160 m).

ARCON96 implements a normal straight-line Gaussian dispersion model with dispersion coefficients that are empirically modified from atmospheric tracer and wind tunnel experimental data to account for low wind meander and aerodynamic effects of buildings on the near-field wind field (e.g., wake and cavity regions) (NRC 1997). Hourly, normalized concentrations (χ/Qs) are calculated from hourly-averaged meteorological data. The hourly values are averaged to develop χ/Qs for five periods ranging from 2 to 720 hours in duration (i.e., 0 to 2 hr, 2 to 8 hr, 8 to 24 hr, 1 to 4 days, and 4 to 30 days). Of these time periods, only the 0 to 2 hr interval is used for dose calculations. ARCON96 accounts for wind direction as the averages are formed. To ensure that the most conservative χ/Q was selected for dose calculations, χ/Q determinations were made for 16 different wind directions. As a result, the averages account for persistence in both diffusion conditions and wind direction. Cumulative frequency distributions are prepared from the average relative concentrations. Relative concentrations that are exceeded no more than

5% of the time (i.e., 95th percentile relative concentrations) are determined from the cumulative frequency distributions for each averaging period.

The two-hour atmospheric dispersion factor (χ/Q) for ground-level releases to the site worker at 328 ft (100 m) was calculated by ARCON96 to be 6.1×10^{-4} sec/m^3. The two-hour atmospheric dispersion factor (χ/Q) for ground-level releases to the IOC at 525 ft (160 m) was calculated by ARCON96 to be 2.5×10^{-4} sec/m^3.

5.4.4.2 Consequence Analysis for the Facility Worker

For the facility worker, conservative consequences are qualitatively estimated. The facility worker is assumed to be at the location of the release. Thus, for events evaluated in the preliminary accident analysis involving an airborne release of plutonium or americium, principal SSCs are deterministically applied. For events involving the release of uranium, the unmitigated consequences are estimated to be low and principal SSCs are not applied.

5.4.4.3 Environmental Consequences

A 24-hour average effluent concentration (EC) is calculated for a release to the environment of each of the released radionuclides using the following expression:

$$[\mathrm{EC}]^{X} = \frac{[\mathrm{ST}]/[RF] \times [\chi/\mathrm{Q}]^{\mathrm{RA}} \times [f]_{X}}{(3600 - \mathrm{sec/hr})(24 - \mathrm{hr})} \qquad (5.4\text{-}3)$$

where:

$[\chi/Q]^{RA}$ = atmospheric dispersion factor unique to the restricted area boundary, sec/m^3

The 24-hour average atmospheric dispersion factor $(\chi/Q)^{RA}$ for ground-level releases at the restricted area boundary (171 ft [52 m]) was calculated to be 2.79×10^{-04} sec/m^3 by ARCON96.

Since the radiological consequences to the environment are limited to an airborne effluent concentration and not a respirable quantity, the respirable fraction (RF) in Equation 5.4-3 corrects the source term (Equation 5.4-2) such that the source term reflects an airborne quantity.

Table 5.4-3 lists the radionuclide composition of common materials located in the MFFF that have been evaluated for potential release in the hypothesized accident events.

Values for EC are compared to 5,000 times the values specified in Table 2 of Appendix B to 10 CFR Part 20, which are listed in Table 5.4-3. The ratios of the calculated value to the modified 10 CFR Part 20 value for each radionuclide are summed to ensure that the cumulative limit is satisfied, as follows:

$$\text{Total EC Ratio} = \sum_{X=1}^{X} \frac{[\mathrm{EC}]^{X}}{5000 \times [\mathrm{EC}]^{X}_{10CFR20}} < 1.0 \qquad (5.4\text{-}4)$$

Once unmitigated environmental consequences are established for each event identified in the hazard assessment, events are grouped, and bounding events are established for each of these groupings under each event type. Unmitigated environmental consequences established for each

Table 5.4-1. Consequence Severity Categories Based on 10 CFR §70.61

Consequence Category	Workers	IOC	Environment
3: High (H)	TEDE > 1 Sv (100 rem) > AEGL3, ERPG3	TEDE > 0.25 Sv (25 rem) >30 mg soluble U intake >AEGL2, ERPG2	
2: Intermediate (I)	0.25 Sv < TEDE ≤ 1 Sv (25 rem < TEDE ≤ 100 rem) > AEGL2, ERPG2 but < AEGL3, ERPG3	0.05 Sv < TEDE ≤ 0.25 Sv (5 rem < TEDE ≤ 25rem) > AEGL1, ERPG1 but < AEGL2, ERPG2	radioactive release > 5000 x (Table 2 in Appendix B of 10 CFR Part 20)
1: Low (L)	Events of lesser radiological and chemical exposures to workers than those above in this column	Events of lesser radiological and chemical exposures to the IOC than those above in this column	Radioactive releases producing effects less than those specified above in this column

TEDE – Total Effective Dose Equivalent (see Section 5.4.4.1)
AEGL – Acute Exposure Guideline Level (1, 2, 3 refers to the severity level, see Chapter 8)
ERPG – Emergency Response Planning Guideline (1, 2, 3 refers to the severity level, see Chapter 8)

Note: In the calculation of chemical consequences, AEGLs and ERPGs do not currently exist for all the chemicals used at the MFFF. Therefore, Temporary Emergency Exposure Limits (TEELs) issued by DOE were used. Chapter 8 details these concentration limits and discusses the chemical consequences in general.

Table 5.4-2. Event Risk Matrix

CONSEQUENCE	Highly Unlikely (1)	Unlikely (2)	Not Unlikely (3)
High (3)	3 No Principal SSCs Applied	6 Principal SSCs Applied	9 Principal SSCs Applied
Intermediate (2)	2 No Principal SSCs Applied	4 No Principal SSCs Applied	6 Principal SSCs Applied
Low (1)	1 No Principal SSCs Applied	2 No Principal SSCs Applied	3 No Principal SSCs Applied

LIKELIHOOD

5.5 SAFETY ASSESSMENT RESULTS

This section provides the results of hazard and accident analyses performed to identify the MFFF principal SSCs that provide protection against NPHs, EMMHs, and internally generated events in accordance with the performance requirements of 10 CFR §70.61.

5.5.1 Hazard Assessment

The hazard assessment was performed to identify and evaluate the hazards posed by the MFFF and its associated support facilities. The analysis identified facility hazards, including the locations and quantities of hazardous materials (chemical and radioactive). Events involving the identified hazards were developed and evaluated to estimate unmitigated event likelihood and consequence in accordance with the methods discussed in Section 5.4. Analyses were also performed to identify NPHs and EMMHs that could adversely impact the MFFF.

5.5.1.1 Hazard Identification

This section provides the results of the MFFF hazard identification, including the hazards posed by natural phenomena and external man-made events.

5.5.1.1.1 MFFF Internal Hazards

The hazards associated with the MFFF processes and operations were identified using the Checklist Analysis method as described in Section 5.4.1. To facilitate the hazard identification process, the MFFF was divided into workshops and further subdivided into process units within each workshop. Tables 5.5-1 and 5.5-2 list the workshops, process units, and process support units considered in the MFFF internal hazard assessment. Tables 5.5-3a and 5.5-3b list the radioactive material quantities by facility location and fire area, respectively. The hazardous chemicals used at the MFFF are identified in Table 8-2. Table 5.5-4 summarizes the results of the hazard identification process. General hazardous chemical characteristics and incompatibilities with the associated materials/process conditions are identified for AP and MP process chemicals in Chapter 8 (Table 8-4).

5.5.1.1.2 Natural Phenomena Hazards

NPHs are those MFFF external hazards that arise from natural processes. These hazards are not the result of man-made operations.

A screening process was performed on a comprehensive list of NPHs to identify those NPHs that have the potential to affect MFFF operations. For the purpose of this evaluation, the period of facility operation is conservatively modeled as 50 years. NPHs that are not possible at SRS, or that cannot affect MFFF operations, are screened from further evaluation and are not considered in the MFFF design or operations. NPHs that have a frequency of occurrence of less than 1×10^{-6} per year are designated as beyond design basis, are screened from further evaluation, and are not considered in the MFFF design or operations.

Table 5.5-5 provides a comprehensive list of NPHs initially evaluated, and Table 5.5-6 summarizes the applicable NPHs that could impact MFFF operations. Applicable NPHs are further evaluated and accounted for as necessary in the MFFF design and operations as described in Section 5.5.2.6.

5.5.1.1.3 External Man-Made Hazards

EMMHs are those hazards that arise outside of the MFFF site from the operation of nearby public, private, government, industrial, chemical, nuclear, and military facilities and vehicles. Chapter 1 identifies and describes the location of the facilities and transportation corridors near the MFFF. SRS information, along with a comprehensive set of NRC and DOE documents, is used to develop the initial list of EMMHs.

The major events that result from EMMHs and the potential effects they could have on MFFF operations are as follows:

- A release of radioactive material resulting in exposures to MFFF personnel
- A release of hazardous chemicals resulting in exposures to MFFF personnel
- Explosions that could directly impact MFFF principal SSCs
- Events that result in a loss of offsite power
- Events that result in a fire (and/or resulting smoke) that spreads to the MFFF.

A screening process was performed on the EMMHs to identify those EMMHs that have the potential to affect MFFF operations. Guidance for the screening of EMMHs is based on the information provided in NUREG/CR-4839 (NRC 1992). Table 5.5-7 provides the screening criteria. Table 5.5-8 summarizes the EMMHs identified and the results of the screening process. The applicable EMMHs that could impact MFFF operations are further evaluated and accounted for as necessary in the MFFF design and operations as described in Section 5.5.2.7.

5.5.1.2 Hazard Evaluation

Following hazard identification, hazards were evaluated to identify potential events and to determine the effects of unmitigated events on the facility worker, site worker, IOC, and the environment.

Tables 5A-1 through 5A-14 in Appendix 5A summarize unmitigated events postulated from the identified hazards. These events are sorted by workshop and event type. The events in Appendix 5A apply for each process unit or workshop identified in the item labeled "specific location." Events that impact individual locations are evaluated for each glovebox, AP vessel, or other sub-unit within the specified process unit or workshop based on the MAR provided in Table 5.5-3a. For example, in fire events, the evaluation is based on the total MAR within a given fire area, as provided in Table 5.5-3b. These unmitigated events are evaluated and discussed in Section 5.5.2 according to the event type, except for low consequence events. Events in Tables 5.5-9, 5.5-12, 5.5-15, 5.5-18, 5.5-23, and 5.5-25 are subsets of the total list of events from the hazard assessment in Appendix 5A. Low consequence events are identified in Table 5.5-25 and discussed in Section 5.5.2.11.

The following assumptions were made in the unmitigated event evaluation:

- No credit is taken for prevention or mitigation design features in the determination of unmitigated event frequencies and consequences.
- The site worker is located 328 ft (100 m) away from the facility and is not evacuated during the event.
- The IOC is located at the controlled area boundary, approximately 525 ft (160 m) from the release point and is not evacuated during the event.
- The quantities and location of radiological and chemical inventories are presented in Tables 5.5-3a, 5.5-3b, and 8-2.
- Storage and shipping containers involved in accidents are assumed to contain the maximum allowable quantity of radioactive material.
- For unmitigated events involving the airborne release of plutonium, americium, or highly toxic chemicals to the facility worker's environment, no credit is taken for evacuation of the immediate facility worker, and the unmitigated event consequences to the facility worker are assumed to require principal SSCs.
- The structural integrity of a shipping or storage container is not considered in assessing consequences from an unmitigated event involving a container.
- Passive heat removal provides adequate cooling for decay heat removal for all facility locations, except the 3013 canister storage area. This assumption has been validated by preliminary calculations.

5.5.2 Accident Analysis

This section presents the results of the analysis performed on the event sequences identified in the hazard assessment. Hazard assessment events are categorized by their unmitigated consequences into one of two categories: (1) low consequence, or (2) above low consequence. The consequence threshold is based on the performance criteria of 10 CFR §70.61 described in Section 5.4.1.2.5. For low consequence events, no principal SSCs are required or identified. For events whose consequences have the potential to exceed the low consequence criteria of 10 CFR §70.61, principal SSCs and the associated design bases that will be utilized to satisfy the requirements of 10 CFR §70.61 and 10 CFR §70.64(b) are identified.

The accident analysis methodology is described in Section 5.4. The events are sorted and organized by event type from the hazards assessment provided in Appendix 5A, as described in the following sections. Quantitative bounding mitigated consequences are provided in Section 5.5.3.

5.5.2.1 Loss of Confinement/Dispersal of Nuclear Material Events

5.5.2.1.1 General Description

The MFFF handles plutonium in the form of solutions, powders, green pellets, and sintered pellets. Fuel rods and fuel assemblies are also handled at the MFFF. A dispersal hazard arises from the possible migration of plutonium particles from a primary confinement (e.g., process equipment, gloveboxes, fuel rods, transfer containers, 3013 canisters, welded process equipment, MOX fuel transport cask, 3013 transport cask) into the workplace or the environment.

Confinement of radioactive materials is ensured by the use of static confinement boundaries, generally in conjunction with ventilation systems. Static confinement boundaries restrict leakage out of the confinement boundary. The associated dynamic confinement system maintains a negative pressure with respect to adjacent areas and ensures that airflow is from areas of lower potential contamination into areas of higher potential contamination. For those cases in which dynamic confinement is not utilized in conjunction with static confinement, confinement boundaries are provided by sealed systems (e.g., 3013 containers, transfer containers, and fuel rods). Additional information regarding the confinement systems utilized within the MFFF is contained in Section 11.4.

Events included in this event type include leaks/breaches from primary confinement types into interfacing systems. This section does not include loss-of-confinement events that result from drop events. Drop events resulting in loss-of-confinement events are discussed in Section 5.5.2.3. Other events that may ultimately lead to loss-of-confinement events include fire, explosion, external man-made events, and natural phenomena. These events are treated based on the nature of the initiating event, namely fire, explosion, external man-made phenomena, and natural phenomena, in other parts of Section 5.5.2.

5.5.2.1.2 Causes

Dispersal of radioactive materials may occur if the static boundary of the primary confinement system is damaged, including defects in or damage to the integrity of vessels, pipes, gloveboxes, some process equipment, fuel rod cladding, and nuclear material containers. The following events can cause dispersal of nuclear material or failure of the primary confinement system:

- Failure of negative pressure or a flow perturbation due to failure of the Very High Depressurization Exhaust System
- Breaches of containers or rod confinement boundaries due to confinement handling operations (e.g., by shearing) or process operation failure
- Backflow into lines that penetrate primary and secondary confinement boundaries
- Corrosion-induced confinement failures
- Breaks or leaks of aqueous polishing (AP) process vessels or pipes
- Glove or seal failures on gloveboxes during normal or maintenance operations
- Thermal excursions leading to failure of gloves or seals
- Over- or under-pressurization of gloveboxes or other process equipment due to utility line/flow perturbations.

5.5.2.1.3 Specific Locations

Losses of confinement/nuclear dispersal events are hypothesized to occur in several locations within the MFFF. Each confinement area and confinement type is postulated to fail in the hazard assessment to determine the resulting safety implications.

5.5.2.1.4 Unmitigated Event Consequences

Unmitigated event radiological consequences were established for loss-of-confinement events identified in the hazard assessment. These consequences were used to establish the need for the application of principal SSCs.

5.5.2.1.5 Unmitigated Event Likelihood

The likelihood of occurrence of unmitigated loss-of-confinement events was qualitatively and conservatively assessed: all unmitigated event likelihoods were assumed to be Not Unlikely. Consequently, no postulated internally generated failures were screened due to likelihood considerations.

5.5.2.1.6 Safety Evaluation

This section presents information on event grouping, safety strategies, principal SSCs, and safety function. The event grouping for the loss-of-confinement events is based on the feasibility of employing common prevention/mitigation features to satisfy the performance requirements of 10 CFR §70.61. To adequately account for the facility worker, the loss-of-confinement events were grouped by the unique mechanism (cause) by which the loss-of-confinement event occurs. This event grouping was also utilized for the site worker, the IOC, and the environment. The following event groupings were utilized:

- Over-temperature
- Corrosion
- Small breaches in a glovebox confinement boundary or backflow from a glovebox through utility lines
- Leaks of AP process vessels or pipes within process cells
- Backflow from a process vessel through utility lines
- Rod-handling operations
- Breaches in containers outside gloveboxes due to handling operations
- Over- or under-pressurization of glovebox
- Excessive temperature due to decay heat from radioactive materials
- Glovebox dynamic exhaust failure
- Process fluid line leak in a C3 area outside of a glovebox
- Sintering furnace confinement boundary failure.

Table 5.5-9 presents a mapping of hazard assessment events to their respective event groups. The event representing the bounding unmitigated radiological consequence for each of the respective event groups is identified. It should be noted that events bounded by the event identified with the largest radiological consequence may require the same safety strategy and analogous principal SSCs to satisfy the performance requirements of 10 CFR §70.61. In this manner, loss-of-confinement events are ensured adequate protection.

The following sections describe the safety evaluation for the respective loss-of-confinement event groups. Tables 5.5-10a and 5.5-11 summarize the results of the evaluation for the facility worker, and the IOC and site worker, respectively. Table 5.5-10b summarizes the results of the evaluation for the protection of the environment. Principal SSCs listed in Table 5.5-10b are required only to make the hypothesized event unlikely.

5.5.2.1.6.1 Over-Temperature

A loss-of-confinement event is postulated due to an over-temperature event in a given process operation. This event group includes events that involve high temperature process equipment and/or failure of process equipment that potentially result in high temperatures within a glovebox that exceed the glovebox design criteria, damaging the glovebox and resulting in a release of radioactive material. The event with the bounding radiological consequences for this event group has been identified as an excessive temperature of an AP electrolyzer located in a glovebox. The resulting over-temperature is postulated to result in a release of unpolished PuO_2 in solution from the glovebox into the C3b area.

To reduce the risk to the facility worker and the environment associated with this postulated event group, a safety strategy utilizing prevention features is adopted. The principal SSC identified to prevent these events is the process safety control subsystem. The safety function of the process safety control subsystem is to shut down process equipment prior to exceeding a temperature safety limit. This temperature will be established by considering all material limits associated with the glovebox. Final calculations and specific temperature setpoints will be performed during final design based on the codes and standards identified in Section 11.6.7 to assure that subsequent to the shutdown of process equipment, normal convection cooling is sufficient.

To reduce the risk to the IOC and site worker, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to mitigate this event is the C3 confinement system. The safety function of the C3 confinement system is to provide filtration to mitigate dispersions from the C3 areas.

The prevention features present to protect the facility worker and the environment provide defense-in-depth protection for the site worker and IOC.

5.5.2.1.6.2 Corrosion

A loss-of-confinement event involving a catastrophic failure of a primary confinement boundary (i.e., a laboratory or an AP glovebox containing corrosive chemicals, AP fluid transport systems, a pneumatic transfer line, or ducting of the C4 confinement system) is postulated due to corrosion. Loss-of-confinement events caused by corrosion within process cells are discussed in

Section 5.5.2.1.6.4. Loss-of-confinement events caused by corrosion of pipes containing process fluids within C3 areas not enclosed within a glovebox are discussed in Section 5.5.2.1.6.11. Corrosion may occur either from within or from the outside of process equipment. The event identified with the bounding radiological consequences for this event group is a corrosion event involving the pneumatic transfer system with PuO_2 in a buffer pot. In this event, corrosion occurs from the outside of the transfer system and potentially results in the failure of the pneumatic tube with subsequent dispersal of PuO_2 to the surrounding area.

To reduce the risk to the facility worker and the environment associated with this event group, a safety strategy to mitigate the effects of corrosion is adopted that prevents catastrophic failures to primary confinement boundaries, such as gloveboxes. The principal SSC identified to implement this safety strategy is the use of material maintenance and surveillance programs as appropriate. The safety function of the material maintenance and surveillance programs is to detect and limit the damage resulting from corrosion (principally to reduce failures associated with corrosion occurring to laboratory and AP gloveboxes containing corrosive chemicals, confinement ducting, and pneumatic transfer lines).

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the IOC and site worker. However, the C4 and C3 confinement systems, and the C2 confinement system passive boundary, provide defense-in-depth protection for the IOC and the site worker.

5.5.2.1.6.3 Small Breaches in a Glovebox Confinement Boundary or Backflow From a Glovebox Through Utility Lines

A loss-of-confinement event is postulated to arise due to small breaches (e.g., glove failures) in a C4 glovebox or backflow of material within a glovebox to an interfacing system. The event identified with the bounding radiological consequences for this event group is a backflow of radioactive material from a glovebox through an interfacing supply line that is subsequently breached or opened during a maintenance operation.

To reduce the risk to the facility worker and the environment associated with this event group, a safety strategy utilizing mitigation features has been adopted. The C4 confinement system is identified as the principal SSC preventing this event sequence from impacting the facility worker and the environment. The safety function of the C4 confinement system is to maintain a negative glovebox pressure differential between the glovebox and interfacing systems. The system also maintains inward flow through a small glovebox breach to ensure that no significant quantity of radioactive material escapes the glovebox.

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the IOC or the site worker. However, the C3 confinement system provides defense-in-depth protection for the IOC and the site worker.

5.5.2.1.6.4 Leaks of AP Process Vessels or Pipes Within Process Cells

A loss-of-confinement event is postulated due to a leak inside a process cell. The event identified with the bounding radiological consequences for this event group is a leak of tanks/vessels inside the process cell containing the Liquid Waste Reception Unit.

To reduce the risk to the site worker, the IOC, the facility worker, and the environment associated with this postulated event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the process cell for the facility worker and the process cell exhaust system for the site worker, the IOC, and the environment. The safety function of the process cell is to contain leaks within the process cells. The safety function for the process cell exhaust system is to operate to ensure that a negative pressure exists between the process cell areas and the C2 area and to ensure that the process cell exhaust is effectively filtered.

Process cell entry controls are also identified as a principal SSC for the facility worker. The safety function of the process cell entry controls is to prevent the entry of personnel into process cells during normal operations and to ensure that facility workers do not receive a radiological exposure in excess of limits while performing maintenance in the AP process cells.

The C2 confinement system passive boundary provides defense in depth protection for the IOC, the site worker, and the environment.

5.5.2.1.6.5 Backflow From a Process Vessel Through Utility Lines

A loss-of-confinement event is postulated to occur due to backflow of material from a process vessel to an interfacing system. The event identified with the bounding radiological consequences for this event group is a backflow of radioactive material from a waste tank containing americium through an interfacing supply line that is subsequently breached or opened during a maintenance operation.

To reduce the risk to the facility worker, site worker, IOC, and the environment associated with this event group, a safety strategy utilizing prevention features has been adopted. Backflow prevention features (such as hydraulic seals and gravitational head differences) are identified as the principal SSCs preventing this event sequence from impacting the facility worker, the site worker, and the environment. The safety function of the backflow prevention features is to ensure a pressure boundary exists between process fluids and interfacing systems (e.g., reagent systems) to prevent process fluids from back-flowing into interfacing systems.

The C2 confinement system passive boundary provides defense-in-depth protection for the IOC, as well as for the site worker and the environment for this event group.

5.5.2.1.6.6 Rod Handling Operations

A loss-of-confinement event is postulated due to a breach of one or multiple fuel rods while utilizing fuel rod handling equipment. This event group is utilized to characterize those cases where the engineering design of the primary confinement type (fuel rod) may not sufficiently prevent a radioactive material release from occurring. The event identified with the bounding radiological consequences involves mishandling a tray of fuel rods.

controls. The safety function of the material handling equipment is to limit damage to fuel rods/assemblies during handling operations. The safety function of the material handling controls is to ensure the proper handling of primary confinement types outside of gloveboxes. To mitigate potential releases from impacting the facility worker, facility worker action is identified as a principal SSC. The safety function of this principal SSC is to ensure that facility workers take proper actions to limit radiological exposure as the result of a rod handling event.

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the IOC, the site worker, or the environment. However, the C2 confinement system passive boundary provides defense-in-depth protection for the IOC, site worker, and the environment.

5.5.2.1.6.7 Breaches in Containers Outside Gloveboxes Due to Handling Operations

A loss-of-confinement event is postulated due to a breach in a 3013 canister, transfer container containing plutonium-bearing waste, or other primary confinement types within the C2 or C3 areas outside of a glovebox. The 3013 canisters are used to contain the incoming PuO_2 and are stored in the 3013 storage area. The transfer containers are used to move material removed from gloveboxes during bagout operations from one location in the MFFF to another. Transfer containers are expected to be similar to DOT 7A drums. Other primary confinement types is the term used to describe the bags or other containers used during bagout operations from a glovebox. After removal from the glovebox, these other primary confinement types are placed within the transfer container, then the transfer container is sealed and moved as necessary. These bagout operations occur only in the C3 areas and only sealed transfer containers are moved from a C3 area to a C2 area. The event identified with the bounding radiological consequences is a loss-of-confinement event in which a transfer container containing filters is breached while in the C2 area.

For events associated with this event group occurring within C2 areas, a safety strategy utilizing prevention features is adopted to reduce the risk to the IOC, site worker, facility worker, and the environment. The principal SSCs identified to implement this safety strategy are the transfer container and the 3013 canister. To ensure that these primary confinement devices are properly handled, material handling controls are also identified as principal SSCs. The safety function of the transfer container and the 3013 canister is to withstand the effects of design basis drops (or an equivalent impact) without breaching. The safety function of the material handling controls is to ensure proper handling of primary confinement types. The C2 system passive boundary provides defense-in-depth protection for the IOC, site worker, and the environment.

For events associated with this event group occurring within C3 areas, a safety strategy utilizing both prevention and mitigation features is adopted to reduce the risk to the facility worker. The principal SSCs identified to implement this safety strategy are the transfer container, 3013 canister, and facility worker controls. To ensure that the transfer container and the 3013 canister are properly handled, material handling controls are also identified as principal SSCs. The safety function of the transfer container and the 3013 canister is to withstand the effects of design basis drops (or an equivalent impact) without breaching. The safety function of the material handling controls is to ensure proper handling of primary confinement types. In those cases in which other primary confinement types are utilized within C3 areas (e.g., during bagout operations), facility worker controls ensure that facility workers take proper actions prior to commencing bag-out operations to prevent and/or limit their radiological exposure. Precautions associated with the radiation protection program are implemented prior to beginning these operations (such as the use of a mask) to ensure the facility worker is protected in case a release of radioactive material occurs.

For events associated with this event group occurring within C3 areas, a safety strategy utilizing mitigation features is adopted to reduce the risk to the IOC, site worker, and the environment. The principal SSC identified to implement this safety strategy is the C3 confinement system. The safety function of the C3 confinement system is to effectively filter releases from the C3 area.

The C2 confinement system passive boundary and the preventative features utilized to reduce the risk to the facility worker and the environment provide defense-in-depth protection for the IOC and site worker.

5.5.2.1.6.8 Over- or Under-Pressurization of Glovebox

A loss-of-confinement event is postulated due to over- or under-pressurization of a glovebox. Two distinct events in which a glovebox is over- or under-pressurized are possible, namely, a slow over- or under-pressurization event and a rapid over- or under-pressurization event. The event identified with the bounding radiological consequence is a rapid over-pressurization of the calcining furnace glovebox.

To reduce the risk to the facility worker associated with rapid over- or under-pressurization events, a safety strategy utilizing prevention features is adopted. To implement this safety strategy, glovebox pressure controls are utilized as the principal SSC. The corresponding safety function is to maintain glovebox pressure within design limits.

A slow pressurization of the glovebox may also occur. To reduce the risk to the facility worker associated with slow pressurization events, a safety strategy utilizing mitigation features is adopted. To implement this safety strategy, the following principal SSCs are utilized:

- Process safety control subsystem
- Facility worker action
- Glovebox pressure controls.

The safety function of the process safety control subsystem is to warn operators of glovebox pressure discrepancies prior to exceeding differential pressure limits. The safety function of facility worker action is to ensure that facility workers take proper actions to limit radiological exposure as the result of glovebox over- or under-pressurization. Events that produce a pressure change will be detected by pressure alarms and would cause immediate operator self-protective action. The safety function of glovebox pressure control is to maintain glovebox pressure within design limits.

To reduce the risk to the IOC, site worker and the environment associated with rapid over- or under-pressurization events, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is the C3 and C4 confinement systems. The safety function of the

C3 and C4 confinement systems is to effectively filter releases to mitigate dispersion from C3/C4 areas.

Any release that may occur from a glovebox will be mitigated by the C2 confinement system, thus providing defense-in-depth protection for the IOC and site worker.

5.5.2.1.6.9 Excessive Temperature Due to Decay Heat from Radioactive Materials

Loss-of-confinement events are postulated due to failures in the surrounding structures attributed to increases in temperatures of operating areas due to decay heat generated by radioactive material. Preliminary thermal calculations have been performed to evaluate the effects of temperature on confinement structural materials. Maximum material temperatures were calculated for both normal conditions and hypothetical accident conditions (in which the ventilation and equipment cooling systems are assumed to be shut down). The design basis temperature criteria for confinement structural materials are provided in Section 11.4.11, Gloveboxes. Thermal sources considered in the calculations include:

- Radioactive decay of nuclear materials
- Spontaneous heating of UO_2 due to oxidation (burnback, UO_2 to U_3O_8)
- Operation of electrical/mechanical equipment (electrical motors, mixers, etc)
- Process equipment (calcining furnace, etc.)

The thermal power generated by the decay of nuclear material was calculated as follows:

- Unpolished Pu: 2.9 W/kg of unpolished PuO_2 powder
- Polished Pu: 2.2 W/kg of polished PuO_2 powder

The specific power of UO_2 oxidation is taken into account using the following values:

- If $T < 74°C$ (165.2°F) then $P_{ox} = 0$ W/kg (0 W/lb) of UO_2,
- If 74°C (165.2°F)$< T <$ 340°C (644°F) then $P_{ox} = 1.1$ W/kg (0.499 W/lb) of UO_2,
- If $T > 340°C$ (644°F) then $P_{ox} = 4.63$ W/kg (2.1 W/lb) of UO_2

where T is the powder temperature.

These preliminary calculations have determined that only the 3013 canister storage structure requires long-term cooling to mitigate the effects of decay heat. The specific consequences associated with this event are heating sections of the concrete vault above the concrete design temperature. This event results in reduced capacity for design loads and may require concrete replacement. Even though several days without forced cooling are required for the concrete to exceed its design criteria, principal SSCs are identified to mitigate the potential consequences of this event to the facility worker, the site worker, the IOC, and the environment.

The principal SSC identified to implement this safety strategy is the High Depressurization Exhaust System (part of the C3 confinement system). The safety function of this system is to provide exhaust to ensure that temperatures in the 3013 canister storage structure are maintained within design limits.

5.5.2.1.6.10 Glovebox Dynamic Exhaust Failure

A loss-of-confinement event is postulated due to a loss of negative pressure or a flow perturbation involving the Very High Depressurization Exhaust System. This event could result in a confinement differential pressure reversal. The bounding radiological consequence for this event group could result in the transport of the airborne and entrained material in C4 gloveboxes to leak into the individual process C3 rooms. This material could then ultimately either be filtered by the C3 confinement system or be transported into the C2 area.

To reduce the risk to the facility worker, site worker, the IOC, and the environment associated with this event, prevention features are utilized. The principal SSC identified to implement this safety strategy is the C4 confinement system. The safety function of the C4 confinement system is to operate to ensure that a negative pressure differential exists between the C4 glovebox and the C3 area and to effectively filter C4 exhaust.

The C3 and C2 confinement system passive boundaries provide defense-in-depth protection for the IOC, site worker, and the environment for this event.

5.5.2.1.6.11 Process Fluid Line Leak In a C3 Area Outside of a Glovebox

A loss-of-confinement event is postulated due to a leak from a line carrying a process fluid in a C3 area outside of a glovebox. Similar loss-of-confinement events within process cells are discussed in Section 5.5.2.1.6.4 and within gloveboxes are discussed in Section 5.5.2.3.6.4. The event identified with the bounding radiological consequences for this event group is a leak from a pipe containing plutonium solution from a dissolution electrolyzer. This leak is assumed to occur outside of an AP glovebox into a C3 area potentially occupied by a facility worker as the line transitions from an AP glovebox to another AP glovebox or to a process cell.

To reduce the risk to the facility worker and the environment associated with this event group, a safety strategy utilizing prevention features is adopted. The principal SSC identified to implement this safety strategy is double-walled pipe containing process fluids (e.g., plutonium bearing fluids) within C3 areas, but outside of gloveboxes. The safety function of this principal SSC is to prevent leaks from pipes containing process fluids from leaking into C3 areas.

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the IOC and site worker. However, any release from a pipe into a C3 area will be mitigated by the C3 confinement system, thus providing defense-in-depth protection for the IOC and the site worker.

5.5.2.1.6.12 Sintering Furnace Confinement Boundary Failure

A loss-of-confinement event is postulated due to a breach in the sintering furnace confinement boundary. The sintering furnace shell forms a primary confinement boundary, which is maintained at a slight overpressure with respect to the process room during normal operations. The sintering furnace confinement boundary is considered to fail in one of two ways, namely a slow leakage through the seals and a rapid overpressure event. The event identified with the bounding radiological consequence is a rapid over-pressurization of the Sintering Furnace.

To reduce the risk to the IOC and site worker associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is the C3 confinement system. The safety function of the C3 confinement system is to provide filtration to mitigate dispersions from C3 Areas.

To reduce the risk to the facility worker and the environment, a safety strategy utilizing prevention features is adopted. To implement this safety strategy, sintering furnace pressure controls and the sintering furnace are utilized as the principal SSCs. The safety function for the sintering furnace pressure controls is to maintain sintering furnace pressure within design limits. The safety function for the sintering furnace is to provide a primary confinement boundary.

Seal failures are not expected to occur. However, a local seal defect is conservatively postulated to occur resulting in the release of some of the furnace atmosphere to the furnace process area. The safety strategy is to mitigate the consequences of this event. The principal SSC implementing this strategy is the sintering furnace and the safety function is to minimize the consequences of a leak. With this principal SSC in place, the consequences of this event are evaluated to be low based on design of the furnace and the following operational features: (1) the furnace atmosphere is continually changed out, thus it contains low amounts of airborne radioactive material and (2) the internal furnace pressure is low, thus there is very low energy available to make internal surface contamination airborne, respirable, and dispersed outside of the furnace.

The C2 confinement system passive boundary provides defense in depth protection for the IOC and the site worker. The C3 confinement system passive boundary provides defense in depth protection for the environment.

5.5.2.1.7 Mitigated Event Consequences

Mitigated event consequences for the bounding radiological loss-of-confinement event are addressed in Section 5.5.3.

5.5.2.1.8 Mitigated Event Likelihood

The likelihood of mitigated events is discussed in Section 5.5.4.

5.5.2.1.9 Comparison to 10 CFR §70.61 Requirements

The SA evaluates a comprehensive list of potential loss-of-confinement events. Based on the results of the bounding consequence analysis and the effective application of the principal SSCs identified in Section 5.5.2.1.6, the risks from loss-of-confinement events satisfy the performance requirements of 10 CFR §70.61.

5.5.2.2 Fire Events

5.5.2.2.1 General Description

A fire hazard occurs from the simultaneous presence of combustible materials, an oxygen source, and a sufficient ignition source. The combustion reaction is exothermal and supplies its own energy once started. Combustion is terminated by a lack of combustible material, oxygen, or energy needed to support the fire. A fire can spread from one point to another by conduction, convection, or radiation. The immediate consequence of a fire is the destruction, by combustion or by thermal damage, of elements in contact with the fire.

Fires may result in the following potential consequences:

- Destruction of a confinement boundary (e.g., glovebox walls, vessels walls, rod cladding, HEPA filters)
- Destruction of civil structures (e.g., room walls, building)
- Destruction of equipment contributing to dynamic confinement (e.g., fan, ventilation duct)
- Failure of or damage to utility equipment (e.g., electrical cabinet, fluid pipes)
- Loss of subcritical conditions (e.g., destruction of isolation shields, loss of subcritical geometry, loss of neutron absorber)
- Loss of other principal SSCs
- Release of nuclear and chemical material to the environment.

The magnitude of a fire impact depends on its size and the nature of the resulting damage. Additional information regarding the details of fire areas and fire hazards throughout the MFFF is included in Chapter 7.

5.5.2.2.2 Causes

Causes identified for fire events within the MFFF buildings include the following:

- Short circuits or equivalent events involving electrical equipment (e.g., fans, motor, switch boxes)
- Ignition or combustion of fixed or transient combustibles
- Equipment that operates at high temperatures
- Ignition of a solvent or other flammable/reactive chemical due to an incorrect reagent addition, an external source of ignition, or temperatures that exceed flash points.

5.5.2.2.3 Specific Locations

Fires are postulated to occur in each of the respective fire areas as described in Section 5.5.2.2.4. These fire areas include those areas nearby electrical equipment and/or combustible material and those containing flammable, explosive, and reactive chemicals. Fires are also hypothesized to occur in specific areas where fire accelerants may be present (e.g., combustible solvents). These areas are limited to specific vessels containing solvents in the AP Solvent Recovery Cycle and the AP Purification Cycle. Equipment hypothesized to operate at high temperatures also presents fire hazards. This equipment includes the following:

- Calcination furnace of the AP Oxalic Precipitation and Oxidation Unit
- Electrolyzers of the AP Dissolution Units
- Evaporators of the AP Acid Recovery Unit and the AP Oxalic Mother Liquor Recovery Unit
- Furnace of the MP Sintering Unit
- Welder of the MP Cladding and Decontamination Unit
- Grinder of the MP Grinding Unit
- Torches, heating plates, and evaporators found in the AP/MP laboratory.

In the absence of controls, these areas are more susceptible to an internal fire event than other areas due to their inclusion of at least one of the three elements necessary and sufficient for the development of a fire (i.e., fuel, oxygen, and applied heat). Additional information regarding the locations of fire hazards throughout the MFFF is presented in Chapter 7.

5.5.2.2.4 Unmitigated Event Consequences

Unmitigated event radiological consequences are established for each of the identified hazard events. These consequences are used to establish the need for the application of principal SSCs.

It is conservatively assumed that all of the material at risk within the fire area is involved in the fire. Fire areas are defined as areas that restrict the spread of fires such that they may be modeled as individually isolated areas. Fire areas are isolated through the use of fire barriers.

The radioactive material at risk within each fire area is provided in Table 5.5-3b. The site fire areas (defined in Chapter 7) and the radioactive material within each fire area listed in Table 5.5-3b provide the basis for this radiological consequence analysis. Chapter 7 also provides a general discussion of the criteria and justification for containing fires within the fire areas.

5.5.2.2.5 Unmitigated Event Likelihood

The likelihood of occurrence of unmitigated fire events was qualitatively and conservatively assessed. All unmitigated event likelihoods were assumed to be Not Unlikely. Consequently, no postulated fires resulting from internally generated failures were screened due to likelihood considerations.

5.5.2.2.6 Safety Evaluation

This section presents information on event grouping, safety strategies, principal SSCs, and safety function. The selection of event groupings for fire events is based on the potentially common radiological prevention and mitigation features afforded by specific fire areas, confinement zones, and confinement types (e.g., 3013 canisters). Consequently, the following event groupings are identified:

- AP process cells
- AP/MP C3 glovebox areas
- C1 and/or C2 areas:
  - 3013 canister
  - 3013 transport cask
  - Fuel rod
  - MOX fuel transport cask
  - Waste container
  - Transfer container
  - Final C4 HEPA filter
- Outside the MOX Fuel Fabrication Building
- Facilitywide systems
- Facility.

Table 5.5-12 presents a mapping of hazard assessment events to their respective groups. The event representing the bounding unmitigated radiological consequence for each of the respective event groups is identified. It should be noted that hazard assessment events bounded by the event identified with the largest radiological consequence may require the same safety strategy and analogous principal SSCs to satisfy the performance requirements of 10 CFR §70.61. In this manner, fire events are ensured adequate protection.

The following sections describe the safety evaluation for the respective groupings of fire event groups. Tables 5.5-13a and 5.5-14 summarize the principal SSCs and the safety function for the facility worker, and the IOC and site worker, respectively. Table 5.5-13b summarizes the results of the evaluation for the protection of the environment. Principal SSCs listed in Table 5.5-13b are required only to make the event unlikely.

The FHA is part of the ISA and is an ongoing process during design. For a description of the relationship between the FHA and the ISA, see Chapter 7.

5.5.2.2.6.1 AP Process Cells

Fires are postulated in the AP process cells due to the presence of solvents and other chemicals with flash points that potentially could be exceeded. The AP process cell containing the Liquid Waste Reception Unit tanks was determined to result in the largest radiological consequence and is thereby taken as the bounding fire event for this event group. Although this cell does not contain any solvent or other combustible materials, a fire was conservatively hypothesized to occur in this cell.

To reduce the risk to the IOC, site worker, facility worker, and the environment associated with the fire events within the AP process cells, a safety strategy utilizing prevention features is adopted. The principal SSC identified to implement this safety strategy is the use of process cell fire prevention features. The fire prevention features that effectively reduce the likelihood of the fire event in the AP process cells to highly unlikely include the following:

- The elimination of ignition sources within these cells (including the elimination of electrical equipment)
- The earth grounding of vessels and pipes to avoid ignition by static electricity
- The presence of fire barriers (part of the fire area designation) to ensure that fires do not breach these cell areas
- For cells containing only aqueous solutions, the elimination of all combustible materials from the process cells
- For cells containing solvents or other combustible products necessary for the process, the minimization of all combustibles within the process cells (i.e., no combustibles outside of process equipment)
- Temperatures are maintained at levels that prevent the creation of flammable vapors.

The safety function of these process cell fire prevention features is to ensure that the likelihood of the fire within the process cell is highly unlikely.

It is emphasized that all the materials at risk in process cells are isolated from the process cell environments by sealed vessels and pipes, thereby ensuring a barrier to an improbable fire in a process cell. This feature is important for tanks that will contain solvent, which is a flammable material but not a fire threat by itself.

To ensure that the process cells are isolated from potential fire hazards, the process cells themselves are isolated from adjacent rooms/cells by fire barriers associated with the designation of fire areas. Therefore, fire barriers are also identified as a principal SSC. The safety function of the fire barrier is to isolate the process cell from fire hazards. It should be noted that fire barriers are identified in the facility event group (Tables 5.5-13a, 5.5-13b, and 5.5-14) and are implicitly required for all fire events.

The process cell exhaust system and the passive C2 confinement system provide defense-in-depth protection to mitigate the potential consequences to the IOC, site worker, and the environment.

5.5.2.2.6.2 AP/MP C3 Glovebox Areas

Fires postulated to occur in AP/MP C3 glovebox areas, by causes identified in Section 5.5.2.2.2, have been divided into two subgroups based on the quantity of radiological materials present in each fire area. For fire areas containing gloveboxes that store radiological materials (e.g., the sintered and green pellet glovebox stores), the bounding radiological consequence involves a fire within the PuO_2 buffer storage area. Although the storage areas are large and the combustible loading is low, this bounding fire has been assumed to involve all the radioactive materials in the storage area. For other fire areas containing process gloveboxes, the bounding radiological consequence involves a fire within the fire area containing the final dosing and ball milling units.

Although the combustible loading is low in this fire area, all the radioactive materials of the gloveboxes within this fire area have been assumed to be involved in the fire.

All Gloveboxes

To reduce the risk to the IOC, site worker, and the environment associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the C3 and C4 confinement systems. The safety function of the C3 confinement system is to remain operable during a design basis fire and effectively filter any release. Note that the static portion of the C4 confinement system (e.g., the glovebox) may be damaged as a result of the fire; however, the active portion of the C4 confinement system will remain operational and will effectively filter any release.

As previously described, the facility is designed to restrict fires to a single fire area. These fire areas are regions within the MOX Fuel Fabrication Building, which ensure that any fire that may occur remains localized and does not spread to other areas of the facility. Thus, these fire areas effectively limit the radioactive material at risk for a fire event, as well as limit the potential quantity of material that could impact the mitigating confinement filters. Therefore, fire barriers are identified as a principal SSC to protect the IOC, site worker, and the environment. The safety function of the fire barrier is to limit a fire to a single fire area. It should be noted that fire barriers are identified in the facility event group (Tables 5.5-13a, 5.5-13b, and 5.5-14) and are implicitly required for all fire events

The safety strategy utilized to reduce the risk to the facility worker is to rely upon mitigation features. The principal SSCs identified to implement this safety strategy are facility worker action and facility worker controls. The safety function of facility worker action is to ensure that facility workers take proper actions to limit radiological exposure as the result of fire. The facility worker evacuates the area in the event of a fire. The safety function of facility worker controls is to ensure that facility workers take proper actions prior to commencing maintenance activities to limit radiological exposure, such as utilizing procedures that will ensure that process equipment is devoid of bulk quantities of nuclear materials prior to performing special maintenance activities.

The C2 confinement system passive boundary, and fire detection and suppression systems provide defense-in-depth protection to mitigate the potential consequences for the IOC, site worker, and the environment.

Storage Gloveboxes

In addition to the mitigation features presented above for all gloveboxes, combustible loading controls have also been identified as a principal SSC for storage gloveboxes to further reduce the risk to the IOC, site worker, and the environment associated with this event group. The associated safety function of this principal SSC is to limit the quantity of combustibles, through design and administrative controls, in fire areas containing a storage glovebox such that any fire that may occur will not encompass a large fraction of the stored radiological material. Calculations will be performed as part of the ISA to demonstrate that fires in fire areas containing storage gloveboxes will not impact significant quantities of stored radiological materials.

5.5.2.2.6.3 C1 and/or C2 Areas

A fire within a C1 and/or C2 area is postulated due to the various causes identified in Section 5.5.2.2.2. Seven subgroups have been identified within this event group and are discussed below. Note that for all fires within the C2 area, the C2 confinement system passive boundary provides defense-in-depth protection for the IOC, site worker, and the environment.

3013 Canister

This event group within the C2 area involves a fire affecting 3013 canisters within the 3013 storage area. Although this storage area contains little combustible material, a large fire involving all of the radioactive material in this fire area has been postulated. It should be noted that the storage area is very large and that the radioactive material is sealed within a canning system consisting of three cans, one inside the other. Thus, there are no known mechanisms that could result in a fire that impacts the entire storage area.

To reduce the risk to the IOC, site worker, facility worker, and the environment, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is combustible loading controls. These controls limit the quantity of combustibles in a fire area containing 3013 canisters to ensure that the canisters are not adversely impacted by a fire.

3013 Transport Cask

A fire within the C1 or C2 area is postulated to affect the 3013 transport cask. These casks contain unpolished plutonium powder within 3013 canisters. To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this fire event, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is the 3013 transport cask. The corresponding safety function of the 3013 transport cask is to withstand the design basis fire without breaching. Administrative controls may be required to limit the quantity of combustibles in a fire area containing 3013 transport casks to ensure that the cask design basis fire is not exceeded. Therefore, combustible loading controls have also been identified as a principal SSC.

Fuel Rod

A fire within the C2 area is postulated to affect fuel rods. The corresponding bounding radiological consequence for this event group involves a fire in the fuel assembly storage area. Although the storage area is large and the combustible loading is low, the fire has been assumed to involve all the radioactive materials in the storage area. To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this fire event, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is combustible loading controls. The associated safety function is to limit the quantity of combustibles in a fire area containing fuel rods to ensure that the fuel rods are not adversely impacted by a fire.

MOX Fuel Transport Cask

A fire within the C1 or C2 area is postulated to affect the MOX fuel transport cask. To reduce the risk to the site worker, facility worker, the IOC, and the environment associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSC to implement this safety strategy is the MOX fuel transport cask. The safety function of the MOX fuel transport cask is to withstand the design basis fire without breaching. Administrative controls may be required to limit the quantity of combustibles in a fire area containing MOX fuel transport casks to ensure that the cask design basis fire is not exceeded. Therefore, the combustible loading controls in the fire areas containing MOX fuel transport casks are identified as a principal SSC.

For fires within the C2 area, the C2 confinement system passive boundary provides defense-in-depth protection to mitigate the potential consequences for the site worker, the IOC, and the environment.

Waste Container

A fire within the C2 area is postulated to affect waste containers. To reduce the risk to the facility worker associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSC to implement this safety strategy is facility worker action. The safety function of this principal SSC is to ensure that facility workers take proper actions to limit radiological exposure as the result of fire.

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the IOC, site worker, or the environment.

For fires within the C2 area, the C2 confinement system passive boundary provides defense-in-depth protection to mitigate the potential consequences for the site worker, the IOC, and the environment.

Transfer Container

A fire within the C2 area is postulated to affect the transfer container. To reduce the risk to the facility worker, the IOC, and the environment associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is combustible loading controls. The associated safety function is to limit the quantity of combustibles in a fire area containing transfer containers to ensure that the container is not adversely impacted by a fire.

Due to the low unmitigated consequences of this event, no principal SSCs are required for the site worker; however, combustible loading controls used to protect the facility worker, the IOC, and the environment provide defense-in-depth protection.

Final C4 HEPA Filter

A fire event is postulated to affect the final C4 HEPA filters. Two types of events are possible: (1) a fire in the room containing these filters and (2) a fire in a C4 area venting to these filters. In the first event type, the final C4 HEPA filters are postulated to be impacted by a fire that breaches the HEPA filter housing and allows material from the HEPA filters to pass directly to the stack. The consequences of this event are based on a conservative quantity of material present on the final C4 HEPA filters. In the second event type, a fire in an upstream unit impacts the final C4 HEPA filters. Events associated with this event type are covered in the other event groups covered in this section.

To reduce the risk to the facility worker, site worker, the IOC, and the environment associated with the first event type in this event group, prevention features are utilized. The principal SSC identified to implement this safety strategy is combustible loading controls. Combustible loading controls are required to limit the quantities of combustibles in the filter area to ensure that the final C4 HEPA filters are not adversely impacted by a fire in the filter room.

The C3 confinement system provides defense-in-depth protection to mitigate the potential consequences for the IOC, the site worker, and the environment.

5.5.2.2.6.4 Outside the MOX Fuel Fabrication Building

Fires outside the MOX Fuel Fabrication Building, but on the MFFF site, could impact the MOX structures containing radioactive material. To reduce the risk to the IOC, site worker, facility worker, and the environment associated with these postulated events, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the MOX Fuel Fabrication Building structure, the Emergency Generator Building structure, the waste transfer line, and the Emergency Control Room Air-Conditioning System. The safety function of the MOX Fuel Fabrication Building structure and the Emergency Generator Building structure is to ensure that the structure is designed to withstand external fires and protect principal SSCs and support systems. The safety function of the waste transfer line is to prevent damage to the line from external fires. The safety function of the Emergency Control Room Air-Conditioning System is to ensure habitable conditions for operators.

5.5.2.2.6.5 Facilitywide Systems

Fires are postulated in facilitywide systems that contain or handle radioactive material. The bounding radiological consequence for this event is associated with the pneumatic pipe automatic transfer system.

To reduce the risk to the facility worker and environment associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are facility worker action and combustible loading controls. The safety function of the facility worker action principal SSC is to ensure that facility workers take proper actions to limit radiological exposure as the result of fire. The safety function of the combustible loading controls is to limit the quantity of combustibles in a fire area containing a pneumatic system to ensure that this system is not adversely impacted by a fire.

Due to the low consequences of this event, no principal SSCs are required to protect the IOC and site worker. However, the C3 confinement system and the C2 confinement system passive boundary provide defense-in-depth protection for the IOC, site worker, and the environment.

5.5.2.2.6.6 Facility

Fires that may propagate from one fire area to another or that may encompass the entire facility have been postulated. To reduce the risk to the IOC, site worker, facility worker and the environment associated with these postulated events, a safety strategy utilizing prevention features is adopted. The principal SSC identified to implement this safety strategy is the fire barriers. The safety function of the fire barriers is to ensure that the fire is contained to a fire area. Additionally, as described in Chapter 7, fire suppression and detection systems are provided as necessary to provide defense-in-depth protection. It should be noted that as part of the fire protection program, combustibles are controlled to ensure the fire barrier ratings are adequate. Furthermore, fire propagation through the pneumatic transfer tubes is under evaluation, and IROFS will be added, as appropriate, to prevent the propagation of hot gas/vapor and smoke between interconnected gloveboxes.

In addition, facility worker action is identified as a principal SSC to protect the facility worker. The safety function of this principal SSC is to ensure that facility workers take proper actions to limit radiological exposure as the result of fire.

5.5.2.2.6.7 AP Electrolyzer

A titanium fire involving the AP Electrolyzer is postulated. The titanium fire is postulated to result in an energetic breach of the AP Electrolyzer and the dispersal of radioactive materials.

To reduce the risk to the facility worker, the IOC, the site worker, and the environment associated with this event, a safety strategy utilizing preventive features is adopted. The principal SSCs identified to implement this strategy are maintenance activity controls and the Process Safety Control Subsystem. The safety function of the maintenance activity controls is to isolate power from the electrolyzer when the electrolyzer is drained. The safety function of the Process Safety Control Subsystem is to monitor the electrolyzer for faults that could result in arcing or other imparting of electrical energy with the risk of titanium fire.

The C3 confinement system, the C4 confinement system, and the fire suppression and detection systems provide defense-in-depth protection to mitigate potential consequences to the IOC, the site worker and the environment.

5.5.2.2.7 Mitigated Event Consequences

Mitigated event consequences for the bounding radiological fire event are addressed in Section 5.5.3.

5.5.2.2.8 Mitigated Event Likelihoods

The likelihood of mitigated events is discussed in Section 5.5.4.

5.5.2.2.9 Comparison to 10 CFR §70.61 Requirements

The SA evaluates a comprehensive list of potential fire-related events. Based on the results of the bounding consequence analysis and the effective application of the principal SSCs identified in Section 5.5.2.2.6, the risks from fire-related events satisfy the performance requirements of 10 CFR §70.61.

5.5.2.3 Load Handling Events

5.5.2.3.1 General Description

A load handling hazard is postulated from the presence of lifting or hoisting equipment used during either normal operations or maintenance activities. A load handling event could occur when either the lifted load is dropped or the lifted load or the loading equipment impacts other nearby items containing radioactive materials.

A load handling event could have the following consequences:

- Possible damage to handled loads, resulting in dispersal of radioactive and/or chemical materials
- Possible damage to nearby equipment or structures, resulting in a loss of confinement and/or a loss of subcritical conditions
- Possible damage to process equipment or structures relied on for safety.

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The extent and magnitude of the damage depends on several variables, such as handling height, load weight, and load rigidity.

5.5.2.3.2 Causes

Causes identified for load handling events at the MFFF buildings include the following:

- Failure of handling equipment to lift or support the load
- Failure to follow designated load paths
- Toppling of loads.

5.5.2.3.3 Specific Locations

Load handling events are hypothesized to occur both inside and outside of gloveboxes and in C2 areas where loads may be lifted or moved during both normal operations and potential maintenance activities. These events could also occur in the AP process cells. Finally, load handling events are also hypothesized to occur outside the MOX Fuel Fabrication Building, involving plutonium and MOX fuel in transportation casks, the waste transfer line, and uranium and wastes in containers.

5.5.2.3.4 Unmitigated Event Consequences

Unmitigated event radiological consequences have been established for load handling events identified in the hazard assessment. These consequences were used to establish the need for the application of principal SSCs.

5.5.2.3.5 Unmitigated Event Likelihood

The likelihood of occurrence of unmitigated load handling events was qualitatively and conservatively assessed: all unmitigated event likelihoods were assumed to be Not Unlikely. Consequently, no postulated internally generated failures were screened due to likelihood considerations.

5.5.2.3.6 Safety Evaluation

This section presents information on event grouping, safety strategies, principal SSCs, and safety function. The selection of the event groupings for load handling events is based on the confinement area and confinement type utilized, if applicable. Thus, within the C1 and/or C2 confinement areas, 3013 canisters, 3013 transport casks, fuel rods, MOX fuel transport casks, waste containers, transfer containers, and final C4 HEPA filters are identified as event groups. An additional event group has been identified to represent an impact that could potentially affect multiple confinement areas or types. The event group names are as follows:

- AP process cells
- AP/MP C3 glovebox areas
- C1 and/or C2 areas:
  - 3013 canister
  - 3013 transport cask

  - Fuel rod
  - MOX fuel transport cask
  - Waste container
  - Transfer container
  - Final C4 HEPA filter
- C4 confinement
- Outside the MOX Fuel Fabrication Building
- Facilitywide.

Table 5.5-15 presents a mapping of hazard assessment events to their respective event groups. For each event group, the event representing the bounding unmitigated radiological consequence was identified. It should be noted that hazard assessment events bounded by the event identified with the largest radiological consequence may require the same safety strategy and analogous principal SSCs to satisfy the performance requirements of 10 CFR §70.61. In this manner, load handling events are ensured adequate protection.

The following sections describe the safety evaluation for the respective load handling event groups. Tables 5.5-16a and 5.5-17 summarize the results of the evaluation for the facility worker, and the IOC and site worker, respectively. Table 5.5-16b summarizes the results of the evaluation for the protection of the environment. Principal SSCs listed in Table 5.5-16b are required only to make the hypothesized event unlikely.

5.5.2.3.6.1 AP Process Cells

A load handling event is postulated within the AP process cells. The event with the bounding radiological consequences for this event group has been identified to occur within the AP cell containing the dissolution tanks. The resulting load handling event is postulated to result in a breach of the AP dissolution tanks and subsequent release of unpolished PuO_2 in solution. The vessels contained in this process cell are assumed to be impacted by either a lifting device or a lifted load causing their contents to drop/spill to the floor.

To reduce the risk to the site worker, the IOC, the facility worker, and the environment associated with this postulated event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the process cell for the facility worker and the process cell exhaust system for the site worker, the IOC, and the environment. The safety function of the process cell is to contain fluid leaks (e.g., through the use of drip trays) within the process cells. The safety function for the process cell exhaust system is to ensure that a negative pressure exists between the process cell areas and the C2 area and to ensure that the process cell exhaust is effectively filtered. Process cell entry controls are also identified as a principal SSC for the facility worker. The safety function of the process cell entry controls is to prevent the entry of personnel into process cells during normal operations, thus no load handling occurs in a process cell during normal operations. Additionally, process cell entry controls ensure that facility workers do not receive a radiological exposure in excess of limits while performing maintenance in the AP process cells.

The C2 confinement system passive boundary provides defense in depth protection for the IOC, the site worker, and the environment.

5.5.2.3.6.2 AP/MP C3 Glovebox Areas

A load handling event is postulated in an AP/MP C3 glovebox area. The event with the bounding radiological consequences for this event group has been identified to occur within the gloveboxes that contain Jar Storage and Handling of the MOX Powder Workshop. This load handling event is postulated to result in a breach of a glovebox and the subsequent release of PuO_2 polished powder. Gloveboxes are assumed to be impacted by: (1) the lid of a reusable plutonium oxide can, (2) a lifting device, or (3) a lifted load outside of the glovebox causing its contents to drop to the floor.

To reduce the risk to the IOC and site worker associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is the C3 confinement system. The safety function of the C3 confinement system is to provide filtration to mitigate dispersions from C3 Areas.

The safety strategy and corresponding principal SSCs for the facility worker and the environment are given by consideration of the following cases to which the gloveboxes may be subjected:

- During normal operations, load handling events within gloveboxes that could potentially impact the C4 static boundary
- During normal operations, external glovebox load handling events that could potentially impact the C4 confinement system
- During maintenance operations and special operations (e.g., filter changeout) – [Facility Workers only].

Note: An additional case in which a spill/leak occurs in a glovebox without breaching the glovebox is discussed in Section 5.5.2.3.6.4.

To reduce the risk to the facility worker and the environment during normal operations, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy are material handling controls, the glovebox, and material handling equipment. The safety function of the material handling controls is to prevent impacts to the glovebox during normal operations from loads handled either outside or inside the glovebox that could exceed the glovebox design basis. An additional safety function of material handling controls is to prevent potential overpressurization of the reusable plutonium oxide cans, due to radiolysis or oxidation of Pu(III) oxalate, and its subsequent impact to the glovebox. The safety function of the glovebox is to maintain confinement integrity for design basis impacts. The safety function of the material handling equipment is to prevent impacts to the glovebox, through the use of engineered equipment to reduce the likelihood of failures leading to glovebox breaches.

To reduce the risk to the facility worker during maintenance operations, facility worker controls based on training and procedures supplements the prevention features discussed above. The safety function of this principal SSC is to ensure that facility workers take proper actions prior to maintenance operations to limit radiological exposure.

The C2 confinement system passive boundary provides defense-in-depth protection for the site worker and the IOC.

5.5.2.3.6.3 C1 and/or C2 Areas

A load handling event within a C1 and/or C2 area involves an impact to one of the following:

- 3013 canister
- 3013 transport cask
- Fuel rod
- MOX fuel transport cask
- Waste container
- Transfer container
- Final C4 HEPA filter.

An event group is generated to represent the safety strategy utilized to reduce the risk associated with load handling events for each of the aforementioned events.

3013 Canister

Load handling events within the C2 area could involve 3013 canisters. The event identified with the bounding radiological consequences involves the drop of one 3013 canister onto another 3013 canister each containing unpolished PuO_2 in powder form.

To reduce the risk to the site worker, the IOC, the facility worker, and the environment associated with this load handling event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the 3013 canister and material handling controls. The safety function of the 3013 canister is to withstand the effects of the design basis drop without breaching. The safety function of the material handling controls is to ensure that the design basis lift height of the 3013 canister is not exceeded.

The C2 confinement system passive boundary also provides defense-in-depth for the site worker, the IOC, and the environment.

3013 Transport Cask

Load handling events within the C1 or C2 area could involve 3013 transport casks. The event identified with the bounding radiological consequences involves the drop of a 3013 transport cask containing unpolished PuO_2 in powder form.

To reduce the risk to the site worker, the IOC, the facility worker, and the environment associated with this load handling event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the 3013 transport cask and material handling controls. The safety function of the 3013 transport cask is to withstand the effects of design basis drops without release of radioactive material. The safety functions of the material handling controls are to ensure that the design basis lift height of the 3013 transport cask is not exceeded.

The C2 confinement system passive boundary also provides defense-in-depth for the site worker, the IOC, and the environment.

Fuel Rod

Load handling events within the C2 area could involve fuel rods. The event identified with the bounding radiological consequences involves the drop of a strongback containing three fuel assemblies containing MOX (6%).

To reduce the risk to the facility worker associated with this load handling event group, mitigation features are utilized. The principal SSC identified to implement this safety strategy is facility worker action. The safety function of this principal SSC is to ensure that facility workers take proper actions to limit radiological exposure as the result of a load handling event.

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the IOC, the site worker, or the environment. However, the C2 confinement passive boundary provides defense-in-depth protection for these potential receptors.

MOX Fuel Transport Cask

Load handling events within the C1 or C2 area could involve MOX fuel transport casks. The event identified with the bounding radiological consequences involves the drop of one MOX fuel transport cask containing up to three MOX fuel assemblies.

To reduce the risk to the facility worker and the environment associated with this load handling event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the MOX fuel transport cask and material handling controls. The safety function of the MOX fuel transport cask is to withstand the effects of design basis drops without release of radioactive material. The safety function of the material handling controls is to ensure that the design basis lift height of the MOX fuel transport cask is not exceeded.

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the site worker or the IOC. However, the MOX fuel transport cask also provides defense-in-depth protection for the IOC and site worker.

Waste Container

Load handling events within the C1, C2 or C3 area could involve waste containers (i.e., drums). Waste is packaged inside plastic (e.g., polyethylene) bags, then in drums that are sealed prior to transfer for material accounting, storage, and ultimate shipment. To reduce the risk to the facility worker associated with this load handling event group, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is facility worker action. The safety function of this principal SSC is to ensure that facility workers take proper actions to limit radiological exposure as the result of a load handling event.

Due to the low unmitigated consequences of this event, no principal SSCs are required to protect the IOC, site worker, or the environment. However, for drops in C2 areas, the C2 confinement passive boundary provides defense-in-depth protection for these potential receptors.

Transfer Container

Load handling events within the C2 area may involve transfer containers. The event identified with the bounding radiological consequences involves the drop of a transfer container containing a HEPA filter with PuO_2 in powder form.

To reduce the risk to the site worker, the IOC, the facility worker, and the environment associated with this load handling event group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the transfer container and material handling controls. The safety function of the transfer container is to withstand the effects of design basis drops without breaching. The safety function of the material handling controls is to ensure that the design basis lift height of the transfer container is not exceeded.

The C2 confinement passive boundary provides defense-in-depth protection to the IOC, the site worker, and the environment.

Final C4 HEPA Filter

Load handling events could result in damage to the final C4 HEPA filters. In this event, the final C4 HEPA filters are postulated to be impacted by a load that breaches the HEPA filter housing and allows material from the HEPA filters to pass directly to the stack. Even though these filters will contain very little material, principal SSCs are identified.

To reduce the risk to the facility worker, site worker, the IOC, and the environment associated with this event group, prevention features are utilized. The principal SSC utilized to ensure that load handling events are prevented from impacting the final C4 HEPA filters is material handling controls. The safety function of the material handling controls is to ensure that load handling activities that could potentially lead to a breach in the final C4 HEPA filters do not occur. Administrative material handling controls will ensure that limited load handling activities take place in the vicinity of the C4 final HEPA filters to minimize the possibility of an impact to the filters. There are no cranes or other equipment in the vicinity of the final HEPA filters that could cause a load handling event. As required, necessary precautions will be taken to ensure that no release of radioactive material occurs during maintenance operations.

The C2 confinement system passive boundary provides defense-in-depth protection for the IOC, the site worker, and the environment for load handling events that occur in the C2 area where the final C4 HEPA filters are located.

5.5.2.3.6.4 C4 Confinement

Load handling events are postulated within AP/MP gloveboxes without impacting the glovebox. These load handling events represent a set of off-normal conditions in which spills, leaks, etc., introduce radioactive material into the glovebox environment but do not result in a challenge to the static confinement of the glovebox. The event identified with the bounding radiological consequences involves the spill of unpolished plutonium powder inside a glovebox.

To reduce the risk to the site worker, the IOC, the facility worker, and the environment associated with this event group, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is the C4 confinement system. The safety function of the C4 confinement system is to ensure that C4 exhaust is effectively filtered. The C4 confinement system also functions to maintain a negative glovebox pressure differential between the glovebox and the interfacing system.

The C34 confinement system provides defense-in-depth protection to the IOC, the site worker, and the environment.

5.5.2.3.6.5 Outside the MOX Fuel Fabrication Building

A load handling event is postulated outside the MOX Fuel Fabrication Building. The bounding radiological event identified for this event group is a load handling event involving the waste transfer line.

To reduce the risk to the IOC, the site worker, facility worker, and the environment, a safety strategy utilizing prevention features is adopted. The principal SSC identified to implement this safety strategy is the waste transfer line. The safety function of the waste transfer line is to ensure that it is protected from activities taking place outside the MOX Fuel Fabrication Building.

5.5.2.3.6.6 Facilitywide

This event group represents load handling events in which heavy loads or load handling equipment damages principal structures or primary confinement boundaries of the MOX Fuel Fabrication Building or causes damage to the confinement types discussed in Section 5.5.2.3.6.

To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this postulated event, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy are the MOX Fuel Fabrication Building structures and material handling controls. The safety function of the MOX Fuel Fabrication Building structures is to ensure that structures are qualified for load drops that could potentially impact radioactive material. The safety function of the material handling controls is to prevent load handling events that could breach primary confinements.

5.5.2.3.7 Mitigated Event Consequences

Mitigated event consequences for the bounding radiological load handling event are addressed in Section 5.5.3.

5.5.2.3.8 Mitigated Event Likelihood

The likelihood of mitigated events is discussed in Section 5.5.4.

5.5.2.3.9 Comparison to 10 CFR §70.61 Requirements

The SA evaluates a comprehensive list of load handling events. Based on the results of the bounding consequence analysis and the effective application of the principal SSCs identified in Section 5.5.2.3.6, the risks from load handling events satisfy the performance requirements of 10 CFR §70.61.

5.5.2.4 Explosion Events

5.5.2.4.1 General Discussion

Explosive events within the MFFF could result from the presence of potentially explosive mixtures (H_2, H_2O_2, hydroxylamine nitrate [HAN], tributyl phosphate [TBP] and its degradation products, solvents, azides, hydrazoic acid, plutonium VI oxalate), steam over-pressurizations, and other potential over-pressurization events. These explosion/overpressurization events could either directly or indirectly involve radioactive material (i.e., an explosion may occur in a tank containing radioactive material or in a surrounding tank, which may impact the radioactive material). These events have the potential to release radioactive material and to damage nearby equipment relied on for safety. The major consequences of explosive events are as follows:

- Release of nuclear materials or chemicals to the environment
- Damage to a confinement boundary
- Damage to equipment contributing to dynamic confinement
- Loss of subcritical conditions
- Damage to civil structures
- Damage to other principal SSCs.

These explosion/overpressurization events are postulated to occur inside the MOX Fuel Fabrication Building from process operations, outside the MOX Fuel Fabrication Building from nearby support facilities and the storage of chemicals on the MFFF site, and from laboratory operations.

5.5.2.4.2 Causes

Causes identified for explosion/overpressurization events include the following:

- Loss of scavenging air in units where radiolysis is credible, and subsequent ignition of the hydrogen after reaching its explosive conditions
- Loss of offgas exhaust flow in units where radiolysis is credible, and subsequent ignition of the hydrogen after reaching its explosive conditions
- Pressurizing reactions in vessels or tanks
- Increase in temperature beyond the safety limit in tanks and vessels

- Incorrect chemical addition/reagent preparation
- Excessive introduction of hydrogen into the sintering furnace
- Excessive introduction of liquids into high-temperature process equipment
- Hydrogen accumulation, and its subsequent ignition after reaching explosive conditions
- Plutonium (in valence state VI) oxalate addition to calcining furnace
- Dry-out of azides
- Organic liquid vapor exceeding flammability limits and subsequent ignition
- Excessive heating of solution.

5.5.2.4.3 Specific Locations

Explosive events are postulated to occur in the process and reagent preparation areas of the MOX Fuel Fabrication Building. Outside of the MOX Fuel Fabrication Building, explosions are postulated to occur in support facilities such as the Reagent Processing Building, Gas Storage Area, and the Emergency and Standby Generator Buildings. Specific event locations are provided in Section 5.5.1.

5.5.2.4.4 Unmitigated Event Consequences

Unmitigated event radiological consequences have been established for explosive events identified in the hazard assessment. These consequences are used to establish the need for the application of principal SSCs.

5.5.2.4.5 Unmitigated Event Likelihood

The likelihood of occurrence of unmitigated explosive events was qualitatively and conservatively assessed: all unmitigated event likelihoods are assumed to be Not Unlikely. Consequently, no postulated explosive events are screened due to likelihood considerations.

5.5.2.4.6 Safety Evaluation

This section presents information on event grouping, safety strategies, principal SSCs, and safety function. The selection of the explosion groups is based on the chemicals identified in the MFFF that have the potential to create explosive conditions. Specific explosion/overpressurization event groups that could occur within the MOX Fuel Fabrication Building from process operations are as follows:

- Hydrogen Explosion
- Steam Over-Pressurization Explosion
- Radiolysis Induced Explosion
- HAN Explosion
- Hydrogen Peroxide Explosion
- Solvent Explosion
- TBP-Nitrate (Red Oils) Explosion

- AP Vessel Over-Pressurization Explosion
- Pressure Vessel Over-Pressurization Explosion
- Hydrazoic Acid Explosion
- Metal Azide Explosion
- Pu (VI) Oxalate Explosion
- Electrolysis Related Explosion.

Additional explosion groups include the following:

- Laboratory Explosion
- Outside Explosion (outside the MFFF Building, but on the MFFF site)

Table 5.5-18 presents a mapping of hazard assessment explosion events to their respective event groups.

The following sections describe the safety evaluation for the respective explosion groups. Table 5.5-19 summarizes the explosion event groupings, principal SSCs, and associated safety functions for all receptors.

In addition to the principal SSCs listed in Table 5.5-19, defense-in-depth protection is provided to minimize the risks presented by the explosions postulated to occur inside the MOX Fuel Fabrication Building. The MOX Fuel Fabrication Building final filters and the C2 confinement system passive boundary provide this defense-in-depth protection.

5.5.2.4.6.1 Hydrogen Explosion

A mixture of hydrogen-argon gas is used within the sintering furnaces associated with the sintering process. The use of hydrogen gas introduces the hazards associated with explosions. General explosion events considered include the following: events involving the sintering furnace itself, events involving leaks of the hydrogen-argon gas mixture into a room, events involving the furnace airlocks and associated gloveboxes, events involving the furnace offgas, and events involving startup, shutdown, and earthquake conditions.

Hydrogen also poses an explosion hazard at the hydrogen storage unit and hydrogen-argon mixing station. These units are located outside of the MFFF Building and events involving these units are discussed in Section 5.5.2.4.6.15. Additionally, hydrogen produced from radiolysis is discussed in Section 5.5.2.4.6.3 and hydrogen produced from electrolysis is discussed in Section 5.5.2.4.6.13.

To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSC identified to implement this safety strategy is the process safety control subsystem. The safety function of the process safety control subsystem is to prevent the formation of an explosive mixture of hydrogen within the MFFF associated with the use of the hydrogen-argon gas. Within the MFFF facility includes all locations within the facility including the furnace, process rooms, airlocks, and associated gloveboxes.

DCS is performing detailed analyses of the hydrogen-argon system and associated furnace design and operations as part of the final design (and ISA) to determine specific scenarios that could lead to the formation of an explosive mixture of hydrogen. As necessary, specific controls (such as limiting the hydrogen content in the hydrogen-argon mixture, monitoring for oxygen within the furnace, monitoring for hydrogen outside of the furnace, crediting dilution flow associated with the HDE or VHD systems) to prevent the formation of an explosive mixture of hydrogen will be identified as IROFS and described in the ISA.

5.5.2.4.6.2 Steam Explosion

Steam explosions may be associated with the use of humidifier water in the inlet gas stream to the sintering furnace. Water carryover from the humidifier can lead to the rapid generation of steam within the sintering furnace and potentially result in an explosion.

To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSC identified to implement this safety strategy is the process safety control subsystem. The safety function of the process safety control subsystem is to ensure isolation of sintering furnace humidifier water flow on high water level.

5.5.2.4.6.3 Radiolysis Induced Explosion

Within the MFFF processes, hydrogen is generated as a result of radiolysis of water or other hydrogenous materials. Radiolysis occurs mainly within the AP process where materials in process equipment are exposed to radiation fields and hydrogen is released. Radiolysis may also occur in other locations where waste and byproducts (e.g., contaminated organic waste or organic-additive-bearing scraps) are contained in closed containers. If not removed, the hydrogen can accumulate and present an explosion hazard.

To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy are the offgas treatment system and dilution air provided by the instrument air system. In addition, waste containers (utilized to transfer contaminated organic waste, organic-additive-bearing scraps in closed containers, and other liquid waste) are designated as principal SSCs for protection of the site worker, facility worker, and the environment. The safety function of the instrument air system is to provide sufficient scavenging air to dilute the hydrogen generated during radiolysis such that explosive concentrations of hydrogen do not occur. See Section 11.9 for additional details. The safety function of the offgas treatment system is to provide an exhaust path for the removal of this diluted hydrogen gas in process vessels. The safety function of the waste containers is to ensure that hydrogen buildup in excess of explosive limits does not occur while providing appropriate confinement of radioactive material.

5.5.2.4.6.4 HAN Explosion

Hydroxylamine nitrate (HAN) and nitric acid are used in the AP process to strip plutonium from the solvent after removal of americium, gallium, and other impurities at the extraction step. Hydrazine nitrate is used in conjunction with HAN to impede the HAN reaction with nitrous acid and consequently increase the HAN availability for the plutonium (IV) reduction. Within the AP process, the HAN/hydrazine nitrate and hydrazoic acid (a byproduct of the nitrous acid reaction with hydrazine nitrate) are destroyed in the purification cycle oxidation column, CLMN 6000, and recycling tanks, to prevent the propagation of these reactants, via the aqueous phase, to downstream process units and to the front end of the purification cycle (PULS2000). In addition to the HAN/hydrazine nitrate solution utilized in the AP process, HAN is present within the AP area in a storage tank containing 1.9 M hydroxylamine solution with 0.1 N nitric acid. This tank is used to feed HAN to the AP process.

The HAN interaction with nitrous acid can, under specific conditions discussed below, create an autocatalytic reaction that could result in an explosion and/or over-pressurization event. Control of systems containing both HAN and nitrous acid (i.e., such that nitrous acid concentration does not increase) may be performed either by:

- utilizing a reducing agent (e.g., hydrazine nitrate) that consumes nitrous acid at a rate faster than the rate at which it is being produced by HAN and metal catalyzed reactions, or
- maintaining the temperature, metal impurities, nitric acid concentration, and the HAN concentration within a specified regime for systems not containing hydrazine nitrate.

Another means of contending with HAN-nitrous acid reactions is to ensure that the system is designed for the conditions resulting from the non-autocatalytic reaction between HAN and nitrous acid.

HAN explosions that potentially occur within the MFFF may be characterized by one of the following three cases:

1. Process Vessels containing HAN and hydrazine nitrate without NO_x addition
2. Vessels containing HAN and no hydrazine nitrate
3. Process Vessels containing HAN and hydrazine nitrate with NO_x addition

The safety strategies for these three distinct process applications are presented below.

1. Process Vessels Containing HAN and Hydrazine Nitrate Without NO_x Addition

In AP process vessels where HAN has been introduced to reduce the plutonium valence state from IV to III (e.g., pulse column PULS3000 of the purification cycle), a preventative safety strategy is adopted to reduce the risk to the facility worker, site worker, IOC, and environment. The principal SSCs to implement this safety strategy are the process safety control subsystem and chemical safety control. The safety function of the process safety control subsystem is to ensure that the temperature of the solution containing HAN is limited to temperatures that are within safety limits. The safety function of the chemical safety control is to ensure that the concentration of nitric acid, metal impurities, and HAN introduced in the process are within safety limits.

It should be noted that the presence of hydrazine nitrate is effective in limiting the quantity of nitrous acid in the system due to the fact that its reaction rate with nitrous acid is approximately a factor of 12,000 greater than the autocatalytic reaction of HAN with nitrous acid. Consequently, the presence of hydrazine nitrate also effectively ensures that an autocatalytic reaction does not occur in process vessels with HAN.

2. Vessels Containing HAN and No Hydrazine Nitrate

For vessels in the AP Building (used to feed the AP process) that contain HAN and no hydrazine nitrate (e.g., the 1.9M HAN buffer tank in the Hydroxylamine Nitrate System), a preventative safety strategy is adopted to reduce the risk to the facility worker, site worker, IOC, and environment from an explosion or over-pressurization event that could impact process vessels containing radiological material. The principal SSCs identified to implement this safety strategy are the process safety control subsystem and chemical safety control. The safety function of the process safety control subsystem is to ensure that the temperature of the solution containing HAN is limited to temperatures that are within safety limits. The safety function of the chemical safety control is to ensure that the concentration of nitric acid, metal impurities, and HAN introduced in the process are maintained below their respective safety limits.

An additional concern in systems comprised of HAN and nitric acid, in which there is no hydrazine, is the possible concentration of the HAN and nitrous acid due to evaporation. To reduce the risk to the facility worker, site worker, IOC, and the environment, a preventative safety strategy is adopted. The principal SSC utilized to implement this safety strategy is the chemical safety controls. The safety function of the chemical safety controls is to ensure that the concentration of HAN and nitric acid are maintained below their respective safety limits.

3. Process Vessels containing HAN and Hydrazine nitrate with NO_x Addition

In the AP purification cycle, vessels designed to receive NO_x gases for reaction with hydrazine nitrate, HAN, and hydrazoic acid include: the oxidation column CLMN6000 and recycling tanks. Unlike other AP process vessels, these vessels are designed to destroy hydrazine nitrate, HAN, and hydrazoic acid via reaction with excess nitrous acid produced from the introduction of NO_x. The temperature and pressure rise in these vessels as a result of these reactions are dependent on the concentrations of the reagents introduced into these vessels and the vent size of these vessels.

To reduce the risk to the facility worker, site worker, IOC, and the environment, a preventative safety strategy is adopted. The principal SSCs utilized to implement this safety strategy are chemical safety control, offgas treatment system, and the process safety control subsystem. The safety function of chemical safety control is to limit the concentration of the HAN, hydrazine nitrate, and hydrazoic acid in the system. The safety function of the offgas treatment system is to provide an exhaust path for the removal of off-gases generated during the decomposition of these chemicals, which provides a means for heat transfer/pressure relief for affected process vessels. The safety function of the process safety control subsystem is to control the liquid flowrate into the oxidation column, thereby regulating the quantity of HAN, hydrazine nitrate and hydrazoic acid added to the column ensuring the potential heat evolution and pressure increase do not exceed the design capabilities of the process vessel.

5.5.2.4.6.5 Hydrogen Peroxide Explosion

A solution of 10 wt % hydrogen peroxide is used in the dissolution units. Explosive vapors can be produced from concentrated solutions higher than 75 wt %. To reduce the risk to the facility worker, site worker, IOC, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSC identified to implement this safety strategy is chemical safety control. The safety function of chemical safety control is to ensure that explosive concentrations of hydrogen peroxide do not occur. Details of this event are presented in Section 8.5.

5.5.2.4.6.6 Solvent Explosion

Some units within the AP process are fed with solvent. The potential for explosions exists due to high process temperatures and the possible attainment of a flammable/explosive mixture in the gaseous phase due to excessive heating. Solvent explosions resulting from chemical interactions with strong oxidizers are discussed in the following section. Section 8.5 presents more details related to this event.

To reduce the risk to the facility worker, site worker, IOC, and the environment associated with this postulated event, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy are the process safety control subsystem, process cell fire prevention features, and the offgas treatment system. The safety function of the process safety control subsystem is to ensure the temperature of the solutions containing solvents do not exceed the temperature at which the resulting gaseous phase becomes flammable. The safety function of the process cell fire prevention features is to ensure that fires in process cells are highly unlikely. The safety function of the offgas treatment system is to provide an exhaust path for the removal of gases in process vessels thereby ensuring that an explosive buildup of vapors does not occur.

5.5.2.4.6.7 TBP – Nitrate (Red Oils) Explosion

The acid-catalyzed hydrolysis of TBP and subsequent oxidation of the associated by-products introduces the risk of a runaway reaction and associated over-pressurization event. This risk exists in AP process units that may contain these by-products and reach high temperatures (e.g., acid recovery unit, oxalic mother liquors recovery unit, purification cycle and solvent recovery unit). These energetic reactions may involve TBP, nitric acid, plutonium nitrate TBP adduct, and TBP degradation products due to chemical reactions (nitration/oxidation/hydrolysis) and radiolysis. Runaway reactions involving TBP and nitric acid are referred to as "red-oil reactions."

To reduce the risk to the facility worker, site worker, IOC, and the environment, a preventative safety strategy is adopted. To implement this preventative safety strategy, principal SSCs are established to control the rate of energy production from the exothermic chemical reactions and the amount of energy liberated from the system (e.g., heat transfer). By ensuring that the rate of energy generation does not exceed the rate of heat removal, such runaway reactions are prevented. The principal SSCs established to implement this safety strategy are the offgas treatment system, the process safety control subsystem, and chemical safety control. These controls ensure that a system initially composed of TBP and nitric acid will not runaway and result in over-pressurization of the process vessel.

An additional consideration is the accumulation of organic by-products formed through hydrolysis reactions of TBP. Most notably, butanol and butyl nitrate have been identified as potential by-products that could liberate significant energy when undergoing oxidation. Thus, controls are established to ensure that significant quantities of butanol and/or butyl nitrate do not build up in the process (i.e., in process vessels containing oxidizing agents and potentially exposed to high temperatures). Furthermore, energetic byproducts formed from TBP degradation may also be generated via radiolysis. Consequently, the exposure time of TBP to radiological materials is limited to ensure that unacceptable quantities of butanol and butyl-nitrate do not accumulate in the system from radiolysis.

Additional details pertaining to the identified principal SSCs are presented below. Additional information on the mechanism and safety evaluation for this event is presented in Section 8.5.

Offgas Treatment System

A prerequisite for a runaway reaction is for the energy generation to exceed the heat removal from the system. Venting provides a mechanism by which energy may be effectively transferred from the system and also serves to limit the extent of the energy generation, by allowing for the evacuation of the reactants via evaporation. The heat transfer mechanism afforded by venting is given by providing an exhaust path for evaporated water and nitric acid, which carry off heat from the system. In addition, venting limits the degree of completion of the hydrolysis reactions by allowing the reactants, nitric acid, and by-products (butanol and butyl nitrate) formed through TBP hydrolysis to evaporate from the system. Furthermore, an open system will not lead to higher temperatures prior to the boiling of water and nitric acid and hence, result in diminished reaction rates and energy generation rates compared to a closed system. Thus, the safety function of the offgas treatment system is to provide an exhaust path for aqueous phase evaporative cooling in process vessels, thereby providing a mechanism for heat removal. An additional safety function of the offgas treatment system is to provide venting of vessels/equipment that potentially contain TBP and its associated by-products to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products.

Process Safety Control Subsystem

The process safety control subsystem ensures temperatures in process vessels, which may contain organics, are limited to ensure that the rate of energy generation given by the hydrolysis of TBP and associated oxidation reactions is limited. (That is, the bulk temperature of the solution that may contain degraded organics is restricted to within the safety limits to control the energy generation rate.) To ensure that adequate heat transfer capability is provided, an adequate aqueous phase will be added to ensure that evaporative cooling is sufficient to balance the energy generation. To ensure that a runaway condition does not develop, the process safety control subsystem also ensures that the bulk fluid design basis heatup rate is limited and that the evaporator is stopped and an aqueous phase is added when triggered by either the exceedance of the design basis temperature or the design basis heatup rate. Control of the energy generation in a system initially containing TBP and nitric acid is effectively given by the rate of hydrolysis of

TBP. In addition to the control of temperature, the residence time of organics in the presence of oxidizers, such as nitric acid, and radiation fields is also controlled to limit the quantity of degraded organics that may buildup in the system either through hydrolysis and/or radiolysis.

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Chemical Safety Control

Certain diluents could undergo nitration or radiolysis, introducing more reactive byproducts that could facilitate a runaway reaction. The properties of the diluent have been recognized as contributing a role in the early "red oil" runaway reactions and may have also contributed to the Tomsk event (Section 8.5 provides more details of these events). The diluent may provide both an energy source and a mechanism by which the heat transfer characteristics are degraded (e.g., during heating above a threshold temperature, diluents have been shown to exhibit foaming). Consequently, to provide reasonable assurance that these phenomena do not occur, an additional safety function for chemical safety control is to ensure that a diluent is utilized that does not contain cyclic chain hydrocarbons.

5.5.2.4.6.8 AP Vessel Over-Pressurization Explosion

Over-pressurization of AP tanks, vessels, and piping are postulated as the result of increases in the temperature or exothermic chemical reactions of solutions in, or entering into, tanks or vessels, or as a result of excessive addition of fluids into high temperature environments (e.g., calcining furnace).

To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy include the fluid transport systems, offgas treatment system, and chemical safety controls. The safety function of the fluid transport systems is to ensure that process vessels, tanks, and piping are designed to prevent process deviations from creating over-pressurization events that result in the release of radioactive material. The safety function of the offgas treatment system is to provide an exhaust path for the removal of gases in process vessels thereby preventing over-pressurization conditions. The safety function of the chemical safety controls is to ensure control of the chemical makeup of the reagents and ensure segregation/separation of vessels/components from incompatible chemicals.

5.5.2.4.6.9 Pressure Vessel Over-Pressurization Explosion

This group involves vessels that are identified as pressure vessels. Explosion events related to pressure vessels arise from the MFFF support systems due to the presence of pressurized gas bottles, tanks, or receivers (pressure vessels) within these systems. These pressure vessels could over-pressurize and explode, impacting primary confinements and resulting in a release of radioactive material.

To reduce the risk to the IOC, site worker, facility worker, and the environment associated with this postulated explosion group, a safety strategy utilizing prevention features is adopted. The principal SSCs identified to implement this safety strategy are the pressure vessel controls. The safety function of the pressure vessel controls is to ensure that primary confinements are protected from the impact of pressure vessel failures.

5.5.2.4.6.10 Hydrazoic Acid Explosion

In the AP process, interactions between hydrazine nitrate and nitrous acid result in the formation of hydrazoic acid (hydrogen azide, HN_3), in the process solution. Hydrazoic acid is a relatively weak acid with a low boiling point, making it volatile at room temperature. Under specific conditions, as described in Section 8.5, hydrazoic acid could be explosive and could also lead to the formation of metal azides. A chemical assessment has revealed that three types of hazards might be created by the presence of this material in process solutions:

- An explosion related to a mixture of HN_3 and air
- An explosion related to the distillation and condensation of HN_3 solutions
- An explosion related to the precipitation of metallic azides under dry conditions.

To reduce the risk to the facility worker, site worker, IOC, and the environment for the first two types of hazards above (involving HN_3), a preventative safety strategy is adopted. The principal SSCs to implement this safety strategy are chemical safety control and the process safety control subsystem. The safety function of chemical safety control is: (1) to assure the proper concentration of hydrazine nitrate is introduced into the system, thereby limiting the quantity of hydrazoic acid produced, and (2) to ensure that hydrazoic acid is not accumulated in the process or propagated into the acid recovery and oxalic mother liquors recovery units by either taking representative samples in upstream units or by crediting the neutralization process within the solvent recovery unit. The safety function of the process safety control subsystem is to limit the temperature of the solution, thereby limiting the evaporation rate and resulting vapor pressure of hydrazoic acid and providing reasonable assurance that an explosive concentration of hydrazoic acid does not occur. If the neutralization process is credited, then the process safety control subsystem may have additional safety functions that include assuring control of the flow and concentration of sodium carbonate to the process unit and assuring mixing occurs within the process unit. These functions, if required, will be identified in the ISA.

The third hazard related to metallic azides is addressed in the following section.

5.5.2.4.6.11 Metal Azide Explosions

As noted in Section 5.5.2.4.6.10, hydrazoic acid is generated from the reaction between nitrous acid and hydrazine nitrate and is restricted to the purification cycle and the solvent recovery unit by principal SSCs. The hydrazoic acid may subsequently interact with metal cations leading to the formation of metal azides within these units. In the solvent recovery unit, sodium carbonate and sodium hydroxide in the process of washing the solvent form a sodium azide. Further details of the potential azide reactions in the AP process are discussed in Section 8.5.

To reduce the risk to the facility worker, site worker, IOC, and the environment associated with possible metal azide explosions, a preventative safety strategy is adopted. The principal SSCs to implement this safety strategy are chemical safety control and the process safety control subsystem. The safety functions of chemical safety control are to: (1) ensure that metal azides are not added to high temperature process equipment (e.g., calcining furnace) and (2) ensure that the sodium azide has been destroyed prior to transfer of the alkaline waste into the high alpha waste of the waste recovery unit. The safety function of the process safety control subsystem is to ensure that metal azides are not exposed to temperatures that would supply sufficient energy to overcome the activation energy needed to initiate the energetic azide decomposition and limit and control conditions under which dry-out can occur.

5.5.2.4.6.12 Pu(VI) Oxalate Explosion

Formation of plutonium (VI) oxalate is discussed in Section 8.5. If this plutonium (VI) oxalate were to be introduced into the calcining furnace in the oxalic precipitation and oxidation unit, then an energetic release attributed to the rapid decomposition of the oxalate via the oxidation by plutonium (VI) oxalate may occur.

To reduce the risk to the facility worker, site worker, IOC, and the environment, a preventative safety strategy is utilized. The principal SSC identified to implement this safety strategy is chemical safety control. The safety function of the chemical safety control is to perform a measurement of the valency of the plutonium prior to adding oxalic acid to the oxalic precipitation and oxidation unit. Determination of the plutonium valency and subsequent termination of feed to the precipators where oxalic acid is added ensures that plutonium (VI) oxalate cannot be produced and therefore cannot enter the calcining furnace.

5.5.2.4.6.13 Electrolysis Related Explosion

The dissolution unit and the dechlorination and dissolution unit utilize a catholyte loop in which nitric acid is used to dissolve plutonium oxide. This electrolytic dissolution process introduces the risk of generating appreciable amounts of hydrogen, which poses an explosion hazard. To reduce the risk to the facility worker, site worker, IOC, and the environment, a preventative safety strategy is adopted. This safety strategy ensures that an explosive mixture of hydrogen is not produced. This safety strategy is implemented with the process safety control subsystem, which will limit the generation of hydrogen. More specifically, the process safety control subsystem ensures that the normality of the acid is sufficiently high to ensure that the off-gas is not flammable.

5.5.2.4.6.14 Laboratory Explosion

Explosions within the MFFF laboratory are postulated to occur as a result of operator error or equipment failure within the laboratory.

To reduce the risk to the facility worker, a safety strategy utilizing both prevention and mitigation features is adopted. The principal SSCs identified to implement this safety strategy include chemical safety control, controls on radiological/chemical material quantities contained in the laboratory, and facility worker actions. Chemical safety control minimizes the likelihood of explosions by ensuring the chemical makeup of laboratory reagents is correct and that incompatible chemicals are segregated. Laboratory material controls will minimize the quantity of hazardous material available for dispersion following an explosion and also minimize the extent of any potential explosion. Facility worker actions to don respiratory protection and evacuate the laboratory mitigate the effects of a potential laboratory explosion. These features will ensure that the performance requirements of 10 CFR §70.61 are satisfied.

To reduce the risk to the site worker, IOC, and the environment, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is the C3 confinement system. The safety function of the C3 confinement system is to mitigate dispersions from the C3 areas. Calculations will be performed as part of the ISA to demonstrate that laboratory explosions and the resulting pressure waves will not impact process operations and to demonstrate the effectiveness of the ventilation system following a laboratory explosion.

The C2 confinement system passive boundary provides defense-in-depth protection for the IOC, site worker, and the environment.

5.5.2.4.6.15 Outside Explosion

Outside explosion events occurring within the MFFF site that could potentially impact MFFF operations or required support systems are postulated in the following specific areas:

- Reagent Processing Building
- Gas Storage Area
- Emergency Generator Building
- Standby Generator Building
- Access Control Building (Armory).

The explosion events evaluated include those involving both the onsite storage and delivery of flammable gases and liquids to the MFFF site. The effects of explosion-generated missiles are also evaluated. Explosions external to the restricted area are discussed in Section 5.5.2.7.

To reduce the risk to the facility worker, site worker, IOC, and the environment associated with this explosion group, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are the MOX Fuel Fabrication Building structure, Emergency Generator Building structure, the waste transfer line, and administrative controls on the delivery of hazardous materials to the MFFF. The safety function of the structures of the MOX Fuel Fabrication Building and Emergency Generator Building is to maintain structural integrity and prevent damage to internal SSCs. The safety function of the waste transfer line is to prevent damage to the line from outside explosions. The safety function of the hazardous material delivery controls is to ensure the quantity of delivered hazardous material and its proximity to the MOX Fuel Fabrication Building structure, Emergency Generator Building structure, and the waste transfer line are controlled to within the bounds of the values used to demonstrate that the consequences of these outside explosions are acceptable. Calculations involving energies, pressures, distances, building structures, etc. will be performed as part of the ISA to demonstrate the effectiveness of the principal SSCs specified for this event.

5.5.2.4.7 Mitigated Event Consequences

Mitigated consequences for the bounding explosion event are addressed in Section 5.5.3.

5.5.2.4.8 Mitigated Event Likelihoods

The likelihood of mitigated events is discussed in Section 5.5.4.

5.5.2.4.9 Comparison to 10 CFR §70.61 Requirements

The SA evaluates a comprehensive list of potential explosion events. Based on the results of the bounding consequence analysis and the effective application of the principal SSCs identified in Section 5.5.2.4.6, the risks from explosion events satisfy the performance requirements of 10 CFR §70.61.

5.5.2.5 Criticality Events

5.5.2.5.1 General Description

Criticality is a physical phenomenon characterized by the attainment of a self-sustaining fission chain reaction. Criticality accidents can potentially release a large amount of energy over a short period of time as a result of accidental production of a self-sustaining divergent neutron chain reaction. A criticality hazard arises whenever fissionable materials, such as ^{235}U or ^{239}Pu, are present in sufficient quantities to attain a self-sustaining fission chain reaction under optimal conditions. Criticality depends not only on the quantity of fissionable material present, but also on the size, shape, moderation, and materials present adjacent to the fissionable material that may possibly reflect neutrons back into the fissionable material.

The immediate consequence of a criticality accident is a rapid increase in system thermal power and radiation as a "fission spike" that is generally terminated by heating and thermal expansion of the system. Subsequent spikes of less intensity may occur. Direct radiation produced as a consequence of criticality accidents occurs rapidly and initially over a short duration, with little or no time for personnel to evacuate during its occurrence. Direct radiation is primarily a concern for the facility worker, since radiation shielding afforded by facility structural features and distance will inherently mitigate consequences to site workers and the IOC. Potential consequences of airborne exposure to radioactive material are assessed for the facility worker, site worker, and IOC as well.

Chapter 6 provides a detailed discussion of criticality safety at the MFFF.

5.5.2.5.2 Causes

Causes identified for criticality events at the MFFF include the violation of several safety limits, where applicable, established by the following parameter controls:

- Geometry control
- Mass control
- Density control
- Isotopics control
- Reflection control
- Moderation control
- Concentration control
- Interaction control
- Neutron absorber control
- Volume control

- Heterogeneity control
- Process variable control.

5.5.2.5.3 Specific Locations

Criticality is applicable to operations within the MFFF where fissionable materials, such as ^{235}U or ^{239}Pu, are present in quantities sufficient to attain a self-sustaining fission chain reaction under optimal conditions.

5.5.2.5.4 Unmitigated Event Consequences

Unmitigated event radiological consequences have been established utilizing the guidance for the evaluation of potential radiological consequences of accidental nuclear criticality in a plutonium processing and fuel fabrication plant provided in Regulatory Guide 3.35. The unmitigated event radiological consequences were established for criticality events identified in the hazard assessment. These consequences were used to establish the need for the application of principal SSCs.

5.5.2.5.5 Unmitigated Event Likelihood

This section is not applicable (see Chapter 6).

5.5.2.5.6 Safety Evaluation

As required by 10 CFR §70.61(d), preventive controls and measures are the primary means of protection against criticality events provided at the MFFF. Adherence to the double contingency principle, as required by the baseline design criteria specified by 10 CFR §70.64(a) must be demonstrated. The double contingency principle stipulated in ANSI/ANS-8.1 requires that "process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident can occur." In all cases, no single credible event or failure results in the potential for a criticality accident.

A single event group is utilized to characterize nuclear criticality events within the MFFF. As discussed above, a safety strategy utilizing prevention features is adopted. These prevention features are implemented to ensure adherence to the double contingency principle. Information regarding the development of principal SSCs and their safety function for criticality events is provided in Chapter 6.

In addition to preventive measures, a criticality accident alarm system (CAAS) is provided with detection capability in areas of the MFFF containing process units with criticality accident potential as required by 10 CFR §70.24 (see Chapter 6).

Nuclear criticality safety evaluations will be performed during the ISA process to identify features to preclude nuclear criticality events. The features identified as being required to ensure that the design bases are fulfilled will be designated as principal SSCs and subsequently IROFS. The features listed above are applicable to the following criticality events identified in the hazard assessment and shown in Appendix 5A: AP-25, RC-10, PW-4, PT-9, RD-8, AS-6, MA-8, and WH-7.

5.5.2.5.7 Mitigated Event Consequences

Although criticality events at the MFFF are prevented, a generic hypothetical criticality event is evaluated in Section 5.5.3. The resulting consequences demonstrate that the site worker and the IOC do not receive significant radiological consequences as a result of this event.

5.5.2.5.8 Mitigated Event Likelihood

The likelihood of mitigated criticality events will meet the double contingency principle. This will be demonstrated in the ISA.

5.5.2.5.9 Comparison to 10 CFR §70.61 Requirements

Application of the double contingency principle will ensure that the requirements of 10 CFR §70.61 are satisfied (see Chapter 6 for additional information regarding the criticality evaluation).

5.5.2.6 Natural Phenomena

5.5.2.6.1 General Discussion

This section summarizes the evaluation of credible natural phenomena that have the potential to affect the MFFF during the period of facility operation. Credible natural phenomena that could have an impact on MFFF operations are listed in Table 5.5-6 and include the following:

- Extreme wind
- Earthquake (including liquefaction)
- Tornado (including tornado missiles)
- External fire
- Rain, snow, and ice
- Lightning
- Temperature extreme.

Natural phenomena could result in either the dispersion of radioactive material and hazardous chemicals or a loss of subcritical conditions. Criticality events and chemical events are discussed in Sections 5.5.2.5 and 5.5.2.10, respectively. Natural phenomena are also considered as initiators of other events such as explosions or leaks.

The SA addresses NPHs up to and including design basis accidents. The design bases for applicable NPHs are based on the information presented in Chapter 1. The magnitudes of the design basis NPHs have been selected considering the most severe documented historical event for the MFFF site. The design bases for each NPH are summarized in Table 5.5-20. The selection of annual exceedance probabilities for natural phenomena events is based on the criteria for reactors licensed under 10 CFR 50. The applicable regulatory guides specify recurrence intervals for each design basis event. Demonstration that the MFFF structures satisfy

- Unplanned access to radiation areas
- Human error or equipment failures resulting in accumulation of radioactive material and subsequent over-exposure of personnel.

5.5.2.8.3 Specific Locations

The impact of external exposures has been evaluated throughout the MFFF facilities. Additional information related to the expected dose throughout the facility is contained in Chapter 9.

5.5.2.8.4 Unmitigated Event Consequences

Due to the nature of the radioactive material present in the MFFF and the distance to the controlled area boundary, there is no direct radiation exposure hazard to the IOC or site worker from MFFF operations. The direct radiation exposure hazard to the facility worker is low, also due to the nature of the radioactive material.

5.5.2.8.5 Unmitigated Event Likelihood

The likelihood of occurrence of unmitigated direct radiation events was qualitatively and conservatively assessed: all unmitigated event frequencies were assumed to be Not Unlikely. Consequently, no postulated direct radiation events were screened due to likelihood considerations.

5.5.2.8.6 Safety Evaluation

Due to the low consequences of the external exposure event, no principal SSCs are required. However, the following MFFF features are utilized to ensure that external exposures are as low as reasonably achievable (ALARA):

- Radiation shielding
- Radiological Protection Program
- Restricted access to potential exposure locations.

Additional information describing radiological protection is contained in Chapter 9. The features listed above are applicable to the following external exposure events identified in the hazard assessment and shown in Appendix 5A: MA-7, AP-24, RC-9, PW-3, PT-8, RD-7, AS-5, and WH-6.

5.5.2.8.7 Mitigated Event Consequences

As stated for the unmitigated event consequences, there is no direct radiation exposure hazard to the IOC or site worker from MFFF operations due to the nature of the radioactive material present in the MFFF and the distance to the receptors. The MFFF Radiological Protection Program, radiation shielding, and radiation area access restrictions ensure that the risk associated with a direct exposure event satisfies the performance requirements of 10 CFR Part 70.

5.5.2.8.8 Mitigated Event Likelihoods

This section is not applicable for direct exposure events.

5.5.2.8.9 Comparison to 10 CFR §70.61 Requirements

As described in Section 5.5.2.8.6, the risk of unmitigated direct exposure events satisfies the performance requirements of 10 CFR §70.61.

5.5.2.9 Support System Evaluation

This section identifies the systems and structures that are required to support the principal SSCs and the specific safety functions of these support systems. Based on the safety functions of each principal SSC, the support systems required to ensure the implementation of these safety functions are identified. These support systems are subsequently categorized as principal SSCs. The methodology for identifying required support systems is provided in Section 5.4.

Once established as principal SSCs, the safety functions of these support systems are established by considering how they support the safety function of the principal SSC. Table 5.5-22 summarizes the required support systems and their associated safety functions. Specific components that support the performance of the required safety functions for these SSCs will be identified in the ISA.

5.5.2.10 Chemicals

5.5.2.10.1 General Description

Chemical hazards at the MFFF exist as a result of the delivery, storage and use of hazardous chemicals. Chemical-related events could involve a release of only chemicals or a release of chemicals with radioactive material or a release of a chemical from processing radioactive material. The radiological risks associated with chemical-related events are provided in other sections of this chapter. Chapter 8 describes the chemicals used at the MFFF and the MFFF Chemical Process Safety Program. Chapter 8 also describes the analysis performed to determine chemical consequences resulting from the release of hazardous chemicals. Sections 11.3 and 11.9 describe the MFFF chemical processes.

5.5.2.10.2 Causes

Causes considered for events postulated to result in chemical release at the MFFF include the following:

- Mechanical failure of a vessel, tank, or pipe containing chemicals
- Corrosion failure of a vessel, tank, or pipe containing chemicals
- Failure of a ventilation system that scavenges potentially hazardous chemicals from vessels
- Incorrect chemical addition resulting in a chemical reaction

- Drop of a container containing a hazardous chemical
- Impact of NPHs on the Reagent Processing Building.

5.5.2.10.3 Specific Locations

Accident sequences that may result in the release of a hazardous chemical are postulated to occur in the areas where chemicals are stored or used and in areas where these chemicals may be in transit (e.g., from the Reagent Processing Building to the MOX Fuel Fabrication Building, unloading areas). Table 8-2 lists the inventory of the hazardous chemicals used at the MFFF.

5.5.2.10.4 Unmitigated Event Consequences

Chemical consequences are discussed in Section 5.5.2.10.6.

5.5.2.10.5 Unmitigated Event Likelihood

The unmitigated event likelihood of occurrence of chemical events was qualitatively and conservatively assessed: all unmitigated event likelihoods were assumed to be Not Unlikely. Consequently, no chemical events were screened due to likelihood considerations.

5.5.2.10.6 Safety Evaluation

This section presents information on the event grouping, safety strategies, principal SSCs, and safety function. The grouping of chemical events is based on whether or not the release occurs with a release of radioactive material. The grouping is as follows:

- Events involving a release of hazardous chemicals only from inside or outside the MFFF
- Events involving a release of hazardous chemicals only, produced from licensed material
- Events involving a release of hazardous chemicals and radioactive material.

As described in 10 CFR 70, the term hazardous chemicals produced from licensed material means substances having licensed material as precursor compounds or substances that physically or chemically interact with licensed material, and that are toxic, explosive, flammable, corrosive, or reactive to the extent that they can endanger life or health if not adequately controlled. These include substances commingled with licensed material, but do not include substances prior to process addition to licensed material or after process separation from licensed material.

Table 5.5-23 presents a mapping of hazard assessment chemical events to these three groups.

5.5.2.10.6.1 Events Involving a Release of Hazardous Chemicals Only, from Inside or Outside the MFFF

Events involving a release of hazardous chemicals not produced from licensed material can occur both inside and outside of the MOX Fuel Fabrication Building. Events involving a release of hazardous chemicals result in the following two risks:

- Direct chemical consequences to the IOC, site worker, and facility worker with no impact on radiological safety
- Chemical consequences that impact radiological safety or MFFF operations and may result in a radioactive material release.

Risks posed by the first case are not regulated by 10 CFR Part 70 since they do not impact or directly involve radioactive material. These risks are not discussed further in this section.

In the second case, a release of chemicals has the potential to impact a facility worker and prevent the worker from performing a required safety function and is therefore evaluated. As discussed in Chapter 12, facility workers mainly perform a monitoring role during emergency conditions. To ensure that workers can perform this function, the Emergency Control Room Air-Conditioning System is designated as a principal SSC. Its safety function is to ensure that habitable conditions for workers in the emergency control room are maintained. The HVAC intake for the Emergency Control Room will be monitored to ensure continued habitability for operators in the control room. No facility worker or operator actions outside the control room are required to mitigate the consequences to meet the requirements of 10 CFR §70.61 for a chemical release.

Any adverse impacts to an operator occurring during a release of unregulated material (i.e., material that does not constitute "licensed material or chemicals produced from licensed material") will not result in exceeding the performance requirements of 10 CFR §70.61. The controls that could be impacted by a release of unregulated material are effectively "permissive" (i.e., positive result required before additional processing can continue) and are not required following such a release. These include: chemical safety controls that are administrative and laboratory material controls (i.e., permissive sampling and analysis, etc.); and material handling controls that are either permissive or that fail in a safe state. There are, therefore, no PSSCs required to mitigate an unregulated release.

5.5.2.10.6.2 Events Involving a Release of Hazardous Chemicals Only, Produced from Licensed Material

Events involving a release of hazardous chemicals directly produced from the processing of licensed materials, but not released with radiological materials, are regulated by 10 CFR Part 70. These events may result in chemical consequences that directly impact the IOC, site worker, or facility worker. The results of the bounding chemical consequence analysis described in Chapter 8 indicate that the unmitigated consequences to the site worker and IOC are low from these events. Thus, no principal SSCs are required to protect the IOC or site worker from a release of hazardous chemicals produced from licensed material. However, the consequences to the facility worker have the potential to exceed the performance requirements of 10 CFR 70, thus PSSCs are identified.

Releases of these hazardous chemicals could occur from pipes and process vessels in one of three areas: gloveboxes (e.g., the Dechlorination and Dissolution Unit electrolyzer), process cells, and C3 ventilated areas (e.g., the Dechlorination and Dissolution Unit chlorine offgas scrubbing column). To reduce the risk to the facility worker associated with a release of hazardous chemicals produced from the processing of licensed materials in these three areas, a safety strategy utilizing mitigation features is adopted. The principal SSCs identified to implement this safety strategy are process cell entry controls for leaks occurring in a process cell, the C4 confinement system for leaks occurring in a glovebox, and facility worker action for leaks occurring in C3 ventilated areas.

The safety function of the process cell entry controls is to prevent the entry of personnel into process cells during normal operations and to ensure that workers do not receive a chemical consequence in excess of limits while performing maintenance in the AP process cells. Similarly, the safety function of the principal SSC facility worker action is to ensure that facility workers take proper actions to limit chemical consequences for leaks occurring in C3 ventilated areas. The safety function of the C4 confinement system is to contain a chemical release within a glovebox and provide an exhaust path for removal of the chemical vapors.

5.5.2.10.6.3 Events Involving the Release of Hazardous Chemicals and Radioactive Material

Events involving the release of hazardous chemicals and radioactive material are regulated by 10 CFR Part 70. These events are postulated to occur inside the MOX Fuel Fabrication Building and consist of the event types previously addressed in Section 5.5.2. These events may result in chemical consequences that directly impact the IOC, site worker, or facility worker. The results of the bounding chemical consequence analysis described in Chapter 8 indicate that the unmitigated consequences to the IOC are low from these events. Thus, no principal SSCs are required to protect the IOC from a release of hazardous chemicals. With the potential exception of releases of depleted uranium dioxide and nitrogen dioxide/dinitrogen tetroxide, consequences to the site worker have also been calculated to be low, thus no principal SSCs are required except as noted below.

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The Chapter 8 chemical consequence analysis includes releases of nitric acid at elevated temperatures from the AP process. Since these chemical releases are accompanied by a release of radioactive material, the previously discussed principal SSCs that protect the facility worker from radioactive material releases also provide protection for chemical releases. Thus, no additional principal SSCs are required for these events.

Dinitrogen tetroxide is stored in the Reagents Processing Building in liquefied form and passes through a vaporizer, also located in the Reagents Processing Building, where it is converted to gaseous nitrogen dioxide and other NOx gases prior to entry into the aqueous polishing area. Under normal operations, these gases are reacted with the hydrazine, HAN, and hydrazoic acid that are present with plutonium nitrate in the oxidation column of the Purification Cycle of the Aqueous Polishing process. If these gases or the unreacted nitrogen dioxide/dinitrogen tetroxide gases are released from the stack the consequences to all potential receptors are acceptable (no offgas treatment assumed).

However, if the process fails (e.g., the flow of plutonium nitrate with hydrazine, HAN, and hydrazoic acid is abnormally terminated to the oxidation column) and/or the nitrogen dioxide/dinitrogen tetroxide supplied to the oxidation column flows at an abnormally high rate, then there is the potential for chemical consequences associated with the release of these gases that may have come into contact with licensed materials to be unacceptable to the site worker. To reduce the risk to the site worker, a safety strategy utilizing mitigation features is adopted. The principal SSC identified to implement this safety strategy is the process safety control subsystem. The safety function of the process safety control subsystem is to ensure the flow of nitrogen dioxide/dinitrogen tetroxide is limited (e.g., by active flow controls) to the oxidation column such that chemical consequences to the site worker are acceptable.

Any additional chemical impacts created by this event group are similar to those discussed in Sections 5.5.2.10.6.1 and 5.5.2.10.6.2. Table 5.5-24 summarizes the chemical event groupings, principal SSCs, and associated safety functions.

Although not required to limit the chemical consequences of a leak to satisfy the requirements of 10 CFR §70.61, leak detection is provided for the process cells.

5.5.2.10.7 Mitigated Event Consequences

The mitigated event consequences for these events are low (see Chapter 8 for a discussion of chemical consequences).

5.5.2.10.8 Mitigated Event Likelihoods

The likelihood of mitigated events is discussed in Section 5.5.4.

5.5.2.10.9 Comparison to 10 CFR §70.61 Requirements

The SA evaluates chemical-related events. Based on the results of the bounding consequence analysis and the effective application of the principal SSCs identified in Section 5.5.2.10.6, the risks from chemical-related events satisfy the performance requirements of 10 CFR §70.61.

5.5.2.11 Low Consequence Events

This section presents the events that have been screened from further evaluation due to the unmitigated radiological consequences satisfying the low dose limits (less than intermediate) established by 10 CFR §70.61.

Conservative unmitigated radiological consequences have been established for each of the events included in this screened category utilizing the methodology of Section 5.4.4. The unmitigated event consequences have been evaluated to be low to the IOC, site worker, facility worker, and the environment for each of the events considered in this section. Table 5.5-25 lists the events that have been screened based on low consequences.

Unmitigated quantitative consequences to the site worker and the IOC as a result of these events have been conservatively analyzed to fall clearly into the low category. The unmitigated dose consequences to the facility worker have been qualitatively determined to be low. The basis for this qualitative assessment is that many of these events involve one of the following:

- Small quantities of material at risk
- Material with a low specific activity
- Material not easily converted into respirable airborne particulate (i.e., small release fractions)
- Liquid–liquid interfaces where mass transfer rates are small
- Decay heat insufficient to result in radiological consequences.

Evaluations of events and consequences are limited to the time that the radwaste is under the responsibility of DCS. The scope of the analysis is terminated once DOE takes responsibility for waste shipments. For example, in the loss of confinement event involving the waste container (i.e., the carboy) containing the excess solvent waste from the aqueous polishing process (event GH-14), radiological consequences are established to all receptors for leaks within the MFFF restricted area boundary and are found to be low to all receptors. However, since the DOE will take possession of the waste container within the MFFF restricted area boundary, radiological consequences due to leaks that occur at and outside of the restricted area boundary are not DCS' responsibility. Nevertheless, consequences to the site worker and the IOC from these events are established to be low.

5.5.3 Bounding Consequences Assessment

This section presents the results of the bounding consequence analysis for each event type. It demonstrates that the bounding events result in low consequences as defined by 10 CFR §70.61 for the IOC, site worker, and environment. The events described are derived from the hazard assessment and preliminary accident analysis and represent the events with the largest airborne and respirable source terms.

The potential consequences associated with mitigated events range from no consequences to the bounding consequences presented in this section. The bounding consequences have been established using the methodology presented in Section 5.4.4. Specific values for the factors used to calculate the source term are presented, as appropriate. Constants needed to calculate the total effective dose equivalent (TEDE) and the effluent concentration (EC), such as the dose conversion factors, half-lives, limiting ECs, and atomic masses, are established in the references noted in Section 5.4. Atmospheric dispersion factors, breathing rates, and isotopic fractions for radionuclides contained in polished and unpolished plutonium (the materials that produce the bounding consequences) used to establish the TEDE are established in Section 5.4.4.

Two sets of events are presented: bounding events and bounding low consequence events.

Bounding events are those events with the potential to produce the highest unmitigated consequences for each event type. They are presented to demonstrate that their mitigated consequences satisfy the performance requirements of 10 CFR §70.61 (i.e., low consequence). Criticality and explosion events are prevented by design, thereby satisfying 10 CFR §70.61 requirements. Nonetheless, they are hypothetically assumed to occur, and their mitigated consequences are discussed for completeness.

Bounding low consequence events are those events with the potential to produce the largest low consequence for each event type (i.e., unmitigated consequences are low to the IOC, site worker, and environment, satisfying 10 CFR §70.61 performance requirements without principal SSCs). They are presented for completeness.

Tables 5.5-26 and 5.5-27 summarize the radiological consequences and EC ratio for the bounding events and bounding low consequence events, respectively. Radiological consequence limits are presented in Table 5.4-1. To satisfy the environmental consequences established in Table 5.4-1, the EC ratio must be less than one (see Section 5.4.4.3).

For conservatism, these consequence analyses do not credit the performance of all applicable principal SSCs, defense in depth features, additional protection features, or MFFF operations to mitigate the event. Additionally, the analyses use conservative values as described in CAR Section 5.4. Therefore, the results of these analyses indicate that even under conservative estimates of SSC performance and physical laws, the consequences associated with potential accidents at the MFFF are low.

5.5.3.1 Loss of Confinement

Within the MFFF, radioactive material is confined within confinement boundaries. Primary confinement boundaries include gloveboxes and the associated ventilation systems; welded vessels, tanks, and piping; plutonium storage (inner can) containers; fuel rod cladding; ventilation system ducts and filters; and some process equipment. Secondary confinement boundaries include plutonium storage containers (outer can) and process rooms and the associated ventilation systems. Tertiary confinement systems include process cells and the associated ventilation systems and the MOX Fuel Fabrication Building and associated ventilation systems. This event type considers the loss of one or more of these confinement boundaries.

The bounding loss of confinement event is an event caused by a load handling accident involving the Jar Storage and Handling Unit (see Section 5.5.3.3 for a description of this event). The bounding radiological consequences associated with this event are provided in Table 5.5-26.

The bounding low consequence loss of confinement event is a fire involving the waste drums located in the truck bay (see Section 5.5.3.2 for a description of this event). The bounding radiological consequences associated with this event are provided in Table 5.5-27.

As shown in Tables 5.5-26 and 5.5-27, the radiological consequences to the IOC and to the nearest site worker are low. Consequences to the facility worker are also acceptable since the worker is trained and is either not in the area of the event, or evacuates the area prior to a significant release of radioactive material. Additionally, the EC ratio is less than one and thus satisfies the performance requirements of 10 CFR §70.61.

The MFFF utilizes many features to reduce the likelihood and consequences of these events, as well as other loss-of-confinement events. Key features include reliable and redundant confinement systems; process temperature, pressure, and flow controls; and redundant control systems.

5.5.3.2 Internal Fire

Fires are postulated to occur and are evaluated for each fire area within the MFFF. Fire areas account for the entire combustible loading within the fire area and are designed to contain the fire within the fire area. No unlikely or likely event has been identified that would cause fires to occur simultaneously in multiple fire areas, thus the evaluation is based on a fire impacting one fire area.

The bounding fire event is a fire in the fire area containing the Final Dosing Unit. This unit contains polished plutonium powder for the purpose of down blending the mixed oxide powder to the desired blend for fuel rod fabrication. This fire area is postulated to contain the largest source term for this event type and consequently produces the largest consequences. The evaluation conservatively assumes that a fire occurs in this fire area and impacts the powder found in this area, resulting in a release of radioactive material. The maximum amount of Pu in this fire area is 136 lb (62 kg, see Table 5.5-3b) of PuO_2 powder. Due to the low combustible loading in this fire area, just a small fraction of this material would be expected to be involved in the fire. However, the evaluation conservatively uses the entire fire area inventory in the consequence analysis. The bounding respirable release fraction (RF times ARF) is based on a fire release mechanism for a powder and is equal to 6×10^{-4} (NRC 1998b).[1] Radioactive material made airborne by this event will be filtered prior to being released from the MFFF by a credited filtration system, which is either the VHD or HDE system. The leak path factor (LPF) associated with these systems is conservatively assigned at 1.0×10^{-4} (see Section 5.4.4.4 for additional information related to the LPF).

The bounding low consequence fire event is a fire involving waste drums located in the truck bay. Waste drums are stored inside the MFFF, then moved to the truck bay and placed on a truck for transportation off of the MFFF site. Waste drums contain small amounts of radioactive material (≤ 60 g), and only a small number of waste drums are transported at one time, thus the maximum MAR estimated to be involved in the fire is 240 grams of unpolished plutonium powder. The associated ARF is 5×10^{-4}, the RF is 1.0, and the DR and LPF are both conservatively established at 1.0. Fires that could impact a larger number of waste drums in the waste drum storage area would be effectively filtered, thus producing lower consequences than this event.

As shown in Tables 5.5-26 and 5.5-27, the radiological consequences to the IOC and to the nearest site worker are low. Consequences to the facility worker are also acceptable since the worker is trained and evacuates the area prior to a significant release of radioactive material. Additionally, the EC ratio is less than one and thus satisfies the performance requirements of 10 CFR §70.61.

The MFFF utilizes many features to reduce the likelihood and consequences of these events as well as other fire-related events. Key features include fire barriers, minimization of combustibles and ignition sources, ventilation systems with fire dampers and HEPA filters, qualified canisters and containers, fire suppression and detection systems, and facility worker action (including local fire brigades). Credit for any or all of these considerations would significantly reduce the likelihood and consequences of these and other fire events.

5.5.3.3 Load Handling

A load handling hazard arises from the presence of lifting or hoisting equipment used during either normal operations or maintenance activities. A load handling event occurs when either the lifted load is dropped or the lifted load or lifting equipment impacts other nearby items.

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[1] The bounding respirable release fraction (RF times ARF) is based on a fire release mechanism for a powder. Although NUREG/CR-6410 (NRC 1998b) cites an ARF of 6×10^{-3} and an RF of 0.01 for fires involving nonreactive powders, the technical basis discussion notes that higher RF values were obtained based on tests done with PuO_2 in a high temperature calcining furnace. Since the MFFF has a similar calcining furnace, the release fractions were adjusted to a more conservative value (RF was increased by a factor of 10 to 0.1) based on the technical discussion in NUREG/CR-6410. Therefore, a bounding respirable release fraction of 6×10^{-4} was used for the calculation of radiological consequences for this fire event.

The bounding load handling event is a drop event involving the glovebox in the Jar Storage and Handling Unit. This glovebox holds jars containing MOX powders with up to 20% polished plutonium. This glovebox is postulated to contain the largest source term for this event and therefore produces the largest consequence. The glovebox is postulated to be impacted during maintenance operations by either a lifting device or a lifted load outside of the glovebox, damaging a portion of the glovebox and causing some of its contents to drop to the floor, resulting in a release of radioactive material. The maximum amount of plutonium in this glovebox is approximately 557 lb (254 kg) of polished plutonium powder. Due to the large glovebox size, there is no known mechanism that could damage the entire glovebox and just a small fraction of this amount would be involved in the event. However, the evaluation conservatively uses the entire glovebox inventory in the consequence calculations (i.e., the damage ratio is assumed to be one). The bounding respirable release fraction (RF times ARF) is based on the drop release mechanism for powders and is equal to 6 x 10^{-4} (NRC 1998b). Radioactive material made airborne by this event will be filtered prior to being released from the MFFF by a credited filtration system, which is either the VHD or HDE system. The leak path factor (LPF) associated with these systems is conservatively assigned at 1.0 x 10^{-4} (see Section 5.4.4.4 for additional information related to the LPF).

The bounding low consequence load handing event involves waste drums located in the truck bay. Waste drums are stored inside the MFFF, then moved to the truck bay and placed on a truck for transportation off of the MFFF site. Waste drums contain small amounts of radioactive material($\leq$ 60 g), and only a small number of waste drums are transported at one time, thus the maximum MAR estimated to be involved in the load handling event is 240 grams of unpolished plutonium powder. The associated ARF is 1 x 10^{-3}, the RF is 0.1, and the DR and LPF are both conservatively established at 1.0.

As shown in Tables 5.5-26 and 5.5-27, the radiological consequences to the IOC and to the nearest site worker are low. Consequences to the facility worker are also acceptable since the worker is trained and evacuates prior to a significant release of radioactive material, or has taken precautions during maintenance activities. Additionally, the EC ratio is less than one and thus satisfies the performance requirements of 10 CFR §70.61.

The MFFF utilizes many features to reduce the likelihood and consequences of this event as well as other load-handling events. Key features include load path restrictions, facility worker action (including crane-operating procedures, maintenance procedures, and operator training), qualified canisters, reliable load-handling equipment, and ventilation systems with HEPA filters. Credit for any or all of these considerations would significantly reduce the likelihood and consequences of these and other load handling events.

5.5.3.4 Criticality Event

The MFFF processes are designed to preclude a criticality event through the use of reliable engineered features and administrative controls. Adherence to the double contingency principle, as specified in ANSI/ANS-8.1 (ANSI/ANS 1983), is employed. Simultaneous failure of the design features and administrative controls is highly unlikely.

Although criticality events at the MFFF are prevented, a generic hypothetical criticality event is evaluated. A source term of 10^{19} fissions in solution is evaluated consistent with guidance provided in Regulatory Guide 3.71 (NRC 1998c). Airborne releases and direct radiation result from the criticality. However, the direct radiation contribution to the site worker and the IOC is negligible due to the shielding provided by the building and the distance to these receptors. The evaluation is based on 91.5 lb (41.5 kg) of unpolished plutonium, the maximum tank inventory of plutonium in solution. Airborne releases are calculated consistent with the guidance of Regulatory Guide 3.35 (NRC 1979). The leak path factors for gases and particulate are 1.0 and 1×10^{-4} (NRC 1978a), respectively, where credit is taken for the filtration system remaining effective for the duration of a criticality event. The radiological consequences associated with this hypothetical event for the IOC and site worker are shown in Table 5.5-26.

As shown in Table 5.5-26, the radiological consequences to the IOC and to the nearest site worker would be low. The radiological consequences to a facility worker, however, could exceed the performance requirements of 10 CFR §70.61; for this reason and as a requirement of 10 CFR §70.61(d), this event type is prevented.

5.5.3.5 Explosion Event

Internal explosion events within the MFFF result from the presence of potentially explosive mixtures and potential over-pressurization events. The MFFF processes are designed to preclude explosions through the use of highly reliable principal SSCs. Although explosion events at the MFFF are highly unlikely, a generic hypothetical explosion event within the MOX building is evaluated.

The evaluation conservatively assumes that an explosion occurs and involves the entire material at risk within a process cell. The maximum source term in any process cell is approximately 165 lb (75 kg) of unpolished plutonium in the cell containing the dilution and buffer tanks of the dissolution unit. The evaluation conservatively uses the entire process cell inventory in the consequence calculation (i.e., the damage ratio is assumed to be one). The bounding respirable release fraction (RF times ARF) is conservatively based on the explosive detonation release mechanism and is equal to 0.01 (NRC 1998b). Radioactive material made airborne by this event will be filtered prior to being released from the MOX Fuel Fabrication Building. The effective bounding leak path factor associated with this event is 1×10^{-4} (NRC 1978a). The bounding radiological consequences associated with this event for the IOC and site worker are provided in Table 5.5-26.

As shown in Table 5.5-26, the impacts to the IOC and the site worker would be low. The radiological consequences to a facility worker could exceed the performance requirements of 10 CFR §70.61; hence, this event type is prevented.

5.5.3.6 Direct Radiation Exposure

A direct radiation hazard arises from the presence of radioactive material within the MFFF. Direct radiation exposure events include those events that result in a radiation dose from radiation sources external to the body. Due to the nature of the radioactive material present in the MFFF (and the distance to the IOC and site receptors), there are no accidents at the MFFF that produce a significant direct radiation exposure hazard to the IOC, site worker, or facility worker.

5.5.3.7 Chemical Releases

Chemical consequences as a result of events are established in Chapter 8 and discussed in Section 5.5.2.10. The results of the preliminary chemical evaluation indicate that the chemical consequences to the IOC and site worker are low. These results and the application of principal SSCs ensure that the performance requirements of 10 CFR §70.61 will be satisfied.

5.5.4 Likelihood Assessment

This section provides additional information on the likelihood evaluation associated with the SA. The likelihood evaluation methodology and associated likelihood definitions are provided in Section 5.4.3.

5.5.4.1 Likelihood Assessment Results

An assessment is performed to determine those NPHs and EMMHs that present a credible hazard to the MFFF. The results of this assessment are presented in Section 5.5.1. All credible NPHs and EMMHs are further evaluated in the accident analysis to determine their potential impact on the MFFF. For those NPHs and EMMHs that could impact the MFFF, principal SSCs are specified to satisfy the performance requirements of 10 CFR §70.61.

For events generated by internal hazards, a qualitative likelihood assessment is made in the hazard evaluation. In that evaluation, all unmitigated events are conservatively assumed to be Not Unlikely. Thus, no internally generated unmitigated events are screened out on the basis of likelihood and they are further evaluated to determine potential consequences. As necessary, principal SSCs are specified to satisfy the performance requirements of 10 CFR §70.61.

Unmitigated events are either prevented and/or mitigated through the application of principal SSCs as identified in Section 5.5.2. For events that are prevented, demonstration that the specified principal SSCs reduce the likelihood of occurrence of the event to a level consistent with the performance requirements of 10 CFR §70.61 will be provided in the ISA utilizing the likelihood definitions given in Section 5.4.3. For events that are mitigated, a demonstration that the mitigation features are sufficiently effective and available to satisfy the performance requirements of 10 CFR §70.61 will also be provided in the ISA Summary.

The MFFF general design philosophy, design bases, system design, and commitments to applicable management measures are based on standard nuclear industry practices. Past precedent regarding the conservative nature of traditional engineering practices provides reasonable assurance that the likelihood requirements of 10 CFR §70.61 will be satisfied by the final design. Principal SSCs either are IROFS or presumed to be IROFS (pending results of the ISA), and are controlled as Quality Level 1 in accordance with the management measures described in Chapter 15. These management measures include design, procurement, installation, testing, and maintenance (as appropriate) in accordance with the MOX Project Quality Assurance Plan to ensure adequate availability and reliability, based on the results of the ISA. These elements ensure that applicable industry codes and standards are utilized, adequate safety

Table 5.5-1. MFFF Workshops and Process Units

Process	Workshop	Unit ID	Process Unit Description
Aqueous Polishing	Aqueous Polishing	KDA	PuO_2 Decanning
		KDB	Dissolution
		KPA	Purification Cycle
		KDM	Pre-polishing Milling
		KDD	Dissolution of Chlorinated Feed
		KDR	Recanning
		KWS	Waste Organic Solvent (also called Solvent Waste Reception)
		KPB	Solvent Recovery
		KPC	Acid Recovery
		KPG	Sampling
		KCA	Precipitation - Filtration - Oxidation
		KCB	Homogenization - Sampling
		KCC	PuO_2 Canning
		KCD	Oxalic Mother Liquors Recovery
		KWD	Liquid Waste Reception
		KWG	Off Gas Treatment
MOX Processing	Receiving	DRS	UO_2 Receiving & Storage
		DDP	UO_2 Drum Emptying
		DCP	PuO_2 Receiving
		DCM	PuO_2 3013 Storage
		DCE	PuO_2 Buffer Storage
	Powder	NDD	PuO_2 Can Receiving and Emptying
		NDP	Primary Dosing
		NBX/NBY	Ball Milling Units
		NDS	Final Dosing
		NXR	Powder Auxiliary
		NCR	Scrap Processing

Table 5.5-1. MFFF Workshops and Process Units (continued)

Process	Workshop	Unit ID	Process Unit Description
MOX Processing (cont.)	Powder (cont.)	NTM	Jar Storage and Handling
		NPE/NPF	Homogenization and Pelletizing Units
	Pellets	PFE/PFF	Sintering Furnaces
		PRE/PRF	Grinding Units
		PTE/PTF	Pellet Inspection and Sorting Units
		PQE	Quality Control and Manual Sorting
		PAD	Pellet Repackaging
		PAR	Scrap Box Loading
		PSE	Green Pellet Storage
		PSF	Sintered Pellet Storage
		PSI	Scrap Pellet Storage
		PSJ	Ground and Sorted Pellet Storage
		PML	Pellet Handling
	Cladding and Rod Control	GME	Rod Cladding and Decontamination
		GMK	Rod Tray Loading
		GDE	Rod Decladding
		SXE/SXF	X Ray Inspection
		SEK	Helium Leak Test
		SDK	Rod Inspection and Sorting
		SCE	Rod Scanning
		STK	Rod Storage
		SMK	Rod Tray Handling
	Assembly	TGM	Assembly Mockup Loading
		TGV	Assembly Mounting
		TAS	Assembly Handling and Storage
		TCK	Assembly Dry Cleaning
		TCP	Assembly Dimensional Inspection
		TCL	Assembly Final Inspection
		TXE	Assembly Packaging
	Wastes	VDQ	Waste Storage
		VDT	Waste Nuclear Counting
		VDR	Filter Dismantling
		VDU	Maintenance and Mechanical Dismantling

Tables 5.5-2 and 5.5-3a and 5.5-3b removed under 10 CFR 2.390.

Table 5.5-4. Summary Hazard Identification Table by Workshop/Process Support Group

		AP	MOX Processing						Auxiliaries and Utilities		Confinement	
		Aqueous Polishing	Receiving	Powder	Pellets	Cladding and Rod Control	Assembly	Wastes	Miscellaneous Areas	Outside Support Facilities	HVAC (Dynamic Confinement)	Gloveboxes (Static Confinement)
Hazardous Materials												
	Corrosive Chemicals	X							X	X		X
	Toxic Chemicals	X							X	X		X
	Other Oxidizers	X								X		
	Alkali Metals	X										
	Nitric Acid	X							X			
	Hydroxylamine Nitrate	X										
	Hydrazine	X								X		
	Other Hazardous Materials	X										
Ionizing Radiation Sources												
	Fissile Material	X	X	X	X	X	X	X	X		X	X
	Radioactive Material	X	X	X	X	X	X	X	X	X	X	X
	Radiography Equipment					X						
	Radioactive Sources					X		X				
	Other Ionizing Radiation Sources					X						
Explosive Materials												
	Explosive Gases	X			X	X			X	X	X	
	Explosive Chemicals	X										
	Incompatible Chemicals - Explosive Incompatibility	X								X		X
	Radioactive/Hydrogenous (Radiolysis)	X						X			X	X
	Other Explosive Materials											
Flammable / Combustibles												
	Flammable Gases	X			X				X	X		
	Flammable Liquids	X	X	X		X			X	X		
	Propane											
	Hydrogen/Argon	X			X				X	X		
	Methane/Argon		X	X	X	X	X	X	X			
	Oxygen	X							X	X		
	Solvents	X							X	X		X
	Other Combustibles	X	X	X	X	X	X	X	X	X	X	X
	Pyrophoric Materials	X				X	X					
	Other Flammable/ Combustibles	X										

Table 5.5-4. Summary Hazard Identification Table by Workshop / Process Support Group (continued)

		AP	MOX Processing						Auxiliaries and Utilities		Confinement	
		Aqueous Polishing	Receiving	Powder	Pellets	Cladding and Rod Control	Assembly	Wastes	Miscellaneous Areas	Outside Support Facilities	HVAC (Dynamic Confinement)	Gloveboxes (Static Confinement)
Thermal Sources												
	Furnaces	X			X				X			X
	Evaporators/Boilers	X										
	Electrical Equipment	X	X	X	X	X	X	X	X	X	X	X
	Electrolyzers	X										X
	Grinders			X	X	X						X
	Lasers				X							X
	Heating Plates								X			X
	Other Process Equipment	X	X	X								X
	Welding Equipment	X				X						X
	Bunsen burners								X			
	Radioactive Decay Heat		X	X	X	X	X					X
	Solar											
	Cryogenic											
	Microwave											
	Electric Arc	X										
	Electrical Heating Resistor	X										
	Heater	X								X		
	Incompatible Chemicals - Thermal Release	X								X		
	Other Thermal Sources			X								
Pressure Sources												
	Autoclaves								X			
	Gas Receivers								X	X		
	Pressure Vessels	X			X	X			X	X		
	Steam Header and Steam Lines	X										
	Gas Bottles	X							X	X		
	Other Pressure Sources											

Table 5.5-10b. Summary of Principal SSCs for Environmental Protection From Loss of Confinement Events

Event Group	Principal SSC	Safety Function
Over-temperature	Process Safety Control Subsystem	Shut down process equipment prior to exceeding temperature safety limits
Corrosion	Material Maintenance and Surveillance Programs	Detect and limit the damage resulting from corrosion.
Small breaches in a glovebox confinement boundary or backflow from a glovebox through utility lines	C4 Confinement System	Maintain a negative glovebox pressure differential between the glovebox and the interfacing systems. Maintain minimum inward flow through small glovebox breaches.
Leaks of AP process vessels or pipes within process cells	Process Cell Exhaust System	Operate to ensure that a negative pressure exists between the process cells and the C2 area. Ensure that the process cell exhaust is effectively filtered.
Backflow From a Process Vessel Through Utility Lines	Backflow Prevention Features	Prevent process fluids from back-flowing into interfacing systems
Rod handling operations	None Required	N/A
Breaches in containers outside gloveboxes due to handling operations in C2 and C3 areas	Material Handling Controls (for events in C2 areas)	Ensure proper handling of primary confinement types outside of gloveboxes.
	3013 Canister (for events in C2 areas)	Withstand the effects of design basis drops without breaching.
	Transfer Container (for events in C2 areas)	Withstand the effects of design basis drops without breaching.
	C3 Confinement System (for events in C3 areas)	Provide filtration to mitigate dispersions from the C3 areas.
Over/Under-pressurization of glovebox	C3/C4 Confinement System	Provide filtration to mitigate dispersion from C3/C4 areas.
Excess temperature due to decay heat from radioactive materials	C3 Confinement System	Provide exhaust to ensure that temperatures in the 3013 canister storage structure are maintained within design limits.
Glovebox Dynamic Exhaust Failure	C4 Confinement System	Operate to ensure that a negative pressure differential exists between the C4 glovebox and the C3 area Effectively filter C4 exhaust

Table 5.5-10b. Summary of Principal SSCs for Environmental Protection From Loss of Confinement Events (continued)

Event Group	Principal SSC	Safety Function
Process Fluid Line Leak In a C3 Area Outside of a Glovebox	Double-Walled Pipe	Prevent leaks from pipes containing process fluids from leaking into C3 areas
Sintering Furnace Leak	Sintering Furnace	Provide a primary confinement boundary against leaks into C3 areas
	Sintering Furnace Pressure Controls	Maintain sintering furnace pressure within design limits

Table 5.5-11. Summary of Principal SSCs for IOC and Site Worker Protection from Loss of Confinement Events

Event Group	Principal SSC	Safety Function
Over-temperature	C3 Confinement System	Provide filtration to mitigate dispersions from the C3 areas.
Corrosion	None Required	N/A
Small breaches in a glovebox confinement boundary or backflow from a glovebox through utility lines	None Required	N/A
Leaks of AP process vessels or pipes within process cells	Process Cell Exhaust System	Operate to ensure that a negative pressure exists between the process cells and the C2 area. Ensure that the process cell exhaust is effectively filtered.
Backflow From a Process Vessel Through Utility Lines	Backflow Prevention Features*	Prevent process fluids from backflowing into interfacing systems
Rod handling operations	None Required	N/A
Breaches in containers outside gloveboxes due to handling operations in C2 and C3 areas	Material Handling Controls (for events in C2 areas)	Ensure proper handling of primary confinement types outside of gloveboxes.
	Transfer Container (for events in C2 areas)	Withstand the effects of design basis drops without breaching.
	3013 Canister (for events in C2 areas)	Withstand the effects of design basis drops without breaching.
	C3 Confinement System (for events in C3 areas)	Provide filtration to mitigate dispersions from the C3 areas.
Over/under-pressurization of glovebox	C3/C4 Confinement	Provide filtration to mitigate dispersion from C3/C4 areas.
Excess temperature due to decay heat from radioactive materials	C3 Confinement System	Provide exhaust to ensure that temperatures in the 3013 canister storage structure are maintained within design limits.
Glovebox Dynamic Exhaust Failure	C4 Confinement System	Operate to ensure that a negative pressure differential exists between the C4 glovebox and the C3 area Effectively filter C4 exhaust.

Table 5.5-11. Summary of Principal SSCs for IOC and Site Worker Protection from Loss of Confinement Events (continued)

Event Group	Principal SSC	Safety Function
Process Fluid Line Leak In a C3 Area Outside of a Glovebox	None Required	N/A
Sintering Furnace Leak	C3 Confinement System	Provide filtration to mitigate dispersions from the C3 areas.

Table 5.5-12. Mapping of Hazard Assessment Events to Fire Event Groups

Event Group	General Event Description	Hazard Assessment Events
AP Process Cells	Fires in fire areas within the AP process cells	AP-4*, AP-3, AP-40, HV-17
AP/MP C3 Glovebox Areas	Fires in fire areas in the AP or MP Areas.	GB-1*,RC-4, PW-1, PT-1, PT-2, AP-5, RD-2, RD-3, AP-2, MA-1, AP-1, WH-2, PT-3, GB-2, WH-1
C1 and/or C2 Areas - 3013 Canister	Fire involving 3013 canisters	RC-1*
C1 and/or C2 Areas – Fuel Rod	Fire involving fuel rods or assemblies	AS-1* AS-2, RD-1
C1 and/or C2 Areas - 3013 Transport Cask	Fire involving 3013 transport casks	RC-3*
C1 and/or C2 Areas - MOX Fuel Transport Cask	Fire involving MOX fuel transport cask	AS-11*
C1 and/or C2 Areas - Transfer Container	Transfer containers involved in a fire outside of a C3 area	MA-2*
C1 and/or C2 Areas - Waste Container	Waste Containers involved in a fire	AS-13*, MA-12, RC-16
C1 and/or C2 Areas - Final C4 HEPA filter	Fires involving the areas containing the final C4 HEPA filters	HV-1*
Outside MOX Fuel Fabrication Building	Fires originating outside of the MOX Fuel Fabrication Building	SF-1*, GH-13
Facilitywide Systems	Fires involving systems that cross fire areas	FW-2*, HV-2
Facility	Fire involving more than one fire area	FW-1*
AP Electrolyzer	Titanium fire involving the AP Electrolyzer	AP-51*

* Hazard assessment event with bounding consequences for this event group.

Table 5.5-13a. Fire Event - Summary of Principal SSCs - Facility Worker

Event Group	Principal SSC	Safety Function
AP Process Cells	Process Cell Fire Prevention Features	Ensure that fires in the process cells are highly unlikely
AP/MP C3 Glovebox Areas	Facility Worker Action	Ensure that facility workers take proper actions to limit radiological exposure.
	Facility Worker Controls	Ensure that facility workers take proper actions prior to maintenance activities to limit radiological exposure.
C1 and/or C2 Areas - 3013 Canister	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing 3013 canisters to ensure that the canisters are not adversely impacted by a fire.
C1 and/or C2 Areas - 3013 Transport Cask	3013 Transport Cask	Withstand the design basis fire without breaching.
	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing 3013 transport casks to ensure that the cask design basis fire is not exceeded.
C1 and/or C2 Areas - Fuel Rod	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing fuel rods to ensure that the fuel rods are not adversely impacted by a fire.
C1 and/or C2 Areas - MOX Fuel Transport Cask	MOX Fuel Transport Cask	Withstand the design basis fire without breaching.
	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing MOX fuel transport casks to ensure that the cask design basis fire is not exceeded.
C1 and/or C2 Areas - Waste Container	Facility Worker Action	Ensure that facility workers take proper actions to limit radiological exposure.

Table 5.5-13a. Fire Event - Summary of Principal SSCs - Facility Worker (continued)

Event Group	Principal SSC	Safety Function
C1 and/or C2 Areas - Transfer Container	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing transfer containers to ensure that the containers are not adversely impacted by a fire.
C1 and/or C2 Areas - Final C4 HEPA Filter	Combustible Loading Controls	Limit the quantity of combustibles in the filter area to ensure that the final C4 HEPA filters are not adversely impacted by a fire in the filter room.
Outside MOX Fuel Fabrication Building	MOX Fuel Fabrication Building Structure	Maintain structural integrity and prevent damage to internal SSCs from external fires.
	Emergency Generator Building Structure	Maintain structural integrity and prevent damage to internal SSCs from fires external to the structure.
	Emergency Control Room Air Conditioning System	Ensure habitable conditions for operators
	Waste Transfer Line	Prevent damage to line from external fires.
Facilitywide Systems	Facility Worker Action	Ensure that facility workers take proper actions to limit radiological exposure.
	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing a pneumatic system to ensure that this system is not adversely impacted by a fire.
Facility	Fire Barriers	Contain fires within a single fire area
	Facility Worker Action	Ensure that facility workers take proper actions to limit radiological exposure.
AP Electrolyzer	Maintenance Activity Controls	Isolation of power to the electrolyzer when the electrolyzer is drained
	Process Safety Control Subsystem	Monitor the electrolyzer for electrical faults that could result in arcing or other imparting of electrical energy with the risk of titanium fire

Table 5.5-13b. Summary of Principal SSCs for Environmental Protection From Fire Events

Event Group	Principal SSC	Safety Function
AP Process Cells	Process Cell Fire Prevention Features	Ensure that fires in the process cells are unlikely.
AP/MP C3 Glovebox Areas	C3/C4 Confinement Systems	Remain operable during design basis fire and effectively filter any release.
	Fire Barriers	Contain/limit fires to a single fire area
	Combustible Loading Controls [For Storage Gloveboxes ONLY]	Limit the quantity of combustibles in fire areas containing a storage glovebox such that any fire that may occur will not encompass a large fraction of the stored radiological material.
C1 and/or C2 Areas - 3013 Canister	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing 3013 canisters to ensure that the canisters are not adversely impacted by a fire.
C1 and/or C2 Areas - 3013 Transport Cask	3013 Transport Cask	Withstand the design basis fire without breaching.
	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing 3013 transport casks to ensure that the cask design basis fire is not exceeded.
C1 and/or C2 Areas - Fuel Rod	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing fuel rods to ensure that the fuel rods are not adversely impacted by a fire.
C1 and/or C2 Areas - MOX Fuel Transport Cask	MOX Fuel Transport Cask	Withstand the design basis fire without breaching.
	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing MOX fuel transport casks to ensure that the cask design basis fire is not exceeded.

Table 5.5-13b. Summary of Principal SSCs for Environmental Protection From Fire Events (continued)

Event Group	Principal SSC	Safety Function
C1 and/or C2 Areas - Waste Container	None Required	N/A
C1 and/or C2 Areas - Transfer Container	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing transfer containers to ensure that the containers are not adversely impacted by a fire.
C1 and/or C2 Areas - Final C4 HEPA Filter	Combustible Loading Controls	Limit the quantity of combustibles in the filter area to ensure that the C4 final HEPA filters are not impacted by a filter room fire.
Outside MOX Fuel Fabrication Building	MOX Fuel Fabrication Building Structure	Maintain structural integrity and prevent damage to internal SSCs from external fires.
	Emergency Generator Building Structure	Maintain structural integrity and prevent damage to internal SSCs from fires external to the structure.
	Emergency Control Room Air Conditioning System	Ensure habitable conditions for operators
	Waste Transfer Line	Prevent damage to line from external fires.
Facility Wide Systems	Combustible Loading Controls	Limit the quantity of combustibles in areas containing the pneumatic transfer system to ensure this system is not adversely impacted
Facility	Fire Barriers	Contain fires within a single fire area
AP Electrolyzer	Maintenance Activity Controls	Isolation of power to the electrolyzer when the electrolyzer is drained
	Process Safety Control Subsystem	Monitor the electrolyzer for electrical faults that could result in arcing or other imparting of electrical energy with the risk of titanium fire

Table 5.5-14. Fire Event - Summary of Principal SSCs - IOC and Site Worker

Event Group	Principal SSC	Safety Function
AP Process Cells	Process Cell Fire Prevention Features	Ensure that fires in the process cells are highly unlikely
AP/MP C3 Glovebox Areas	C3/C4 Confinement Systems	Remain operable during design basis fire and effectively filter any release.
	Fire Barriers	Contain/limit fires to a single fire area
	Combustible Loading Controls [For Storage Gloveboxes ONLY]	Limit the quantity of combustibles in fire areas containing a storage glovebox such that any fire that may occur will not encompass a large fraction of the stored radiological material.
C1 and/or C2 Areas - 3013 Canister	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing 3013 canisters to ensure that the canisters are not adversely impacted by a fire.
C1 and/or C2 Areas - 3013 Transport Cask	3013 Transport Cask	Withstand the design basis fire without breaching.
	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing 3013 transport casks to ensure that the cask design basis fire is not exceeded.
C1 and/or C2 Areas - Fuel Rod	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing fuel rods to ensure that the fuel rods are not adversely impacted by a fire.
C1 and/or C2 Areas - MOX Fuel Transport Cask	MOX Fuel Transport Cask	Withstand the design basis fire without breaching.
	Combustible Loading Controls	Limit the quantity of combustibles in a fire area containing MOX fuel transport casks to ensure that the cask design basis fire is not exceeded.

Table 5.5-14. Fire Event - Summary of Principal SSCs - IOC and Site Worker (continued)

Event Group	Principal SSC	Safety Function
C1 and/or C2 Areas - Waste Container	None Required	N/A
C1 and/or C2 Areas - Transfer Container	Combustible Loading Controls[a]	Limit the quantity of combustibles ina fire area containing transfer containers to ensure that the containers are not adversely impacted by fire
C1 and/or C2 Areas - Final C4 HEPA Filter	Combustible Loading Controls	Limit the quantities of combustibles in the filter area to ensure that the C4 final HEPA filters are not impacted by a filter room fire.
Outside MOX Fuel Fabrication Building	Waste Transfer Line	Prevent damage to line from external fires.
	Emergency Control Room Air Conditioning System	Ensure habitable conditions for operators
	MOX Fuel Fabrication Building Structure	Maintain structural integrity and prevent damage to internal SSCs from external fires.
	Emergency Generator Building Structure	Maintain structural integrity and prevent damage to internal SSCs from fires external to the structure.
Facilitywide Systems	None Required	N/A
Facility	Fire Barriers	Contain fires within a single fire area
AP Electrolyzer	Maintenance Activity Controls	Isolation of power to the electrolyzer when the electrolyzer is drained
	Process Safety Control Subsystem	Monitor the electrolyzer for electrical faults that could result in arcing or other imparting of electrical energy with the risk of titanium fire

[a] Required for IOC only

Table 5.5-15. Mapping of Hazard Assessment Events to Load Handling Event Groups

Event Group	Event Description	Hazard Assessment Event
AP Process Cells	Load Handling Events within an AP Process Cell	AP-27*, AP-43
AP/MP C3 Glovebox Areas	Load Handling Events in C3b/glovebox areas	PT-10, GB-8, GB-9*
C1 and/or C2 Areas – 3013 Canister	Load Handling Events within the C2 areas involving 3013 canisters	RC-12*
C1 and/or C2 Areas - 3013 Transport Cask	Load Handling Events involving 3013 Transport Cask	RC-17*
C1 and/or C2 Areas – Fuel Rod	Load Handling Events in the C2 areas involving fuel rods.	AS-7*, AS-9*, RD-10
C1 and/or C2 Areas - MOX Fuel Transport Cask	Load Handling Event involving MOX Fuel Cask	AS-14*
C1 and/or C2 Areas - Waste Container	Loading Handling events in the C2 areas involving Waste Containers	AS-12*, MA-11, RC-15, WH-8
C1 and/or C2 Areas – Transfer Containers	Load Handling Events in the C2 areas involving Transfer Containers	FW-20*
C1 and/or C2 Areas - Final C4 HEPA Filter	Load Handling Events involving the final C4 HEPA filters	HV-15*
C4 Confinement	Leaks or spills within a glovebox	AP-36*, GB-10, RC-7
Outside MOX Fuel Fabrication Building	Load handling events occurring outside the AP/MP Buildings	SF-14*
Facilitywide	Load Handling Events that impact and damage the internal or external MFFF structure	FW-15*, FW-21, RC-13, HV-14, AS-8, RD-9, FW-17

* Hazard assessment event with bounding consequences for this event group.

Table 5.5-16b. Summary of Principal SSCs for Environmental Protection from Load Handling Events

Event Group	Principal SSC	Safety Function
AP Process Cells	Process Cell Exhaust System	Ensure that a negative pressure exists between the process cell areas and the C2 area Ensure that process cell exhaust is effectively filtered.
AP/MP C3 Glovebox Areas	Material Handling Controls	Prevent impacts to the glovebox during normal operations from loads outside or inside the glovebox that could exceed the glovebox design basis.
		Prevent potential overpressurization of the reusable plutonium oxide cans, due to radiolysis or oxidation of Pu(III) oxalate, and its subsequent impact to the glovebox.
	Material Handling Equipment	Prevent impacts to the glovebox through the use of engineered equipment.
	Glovebox	Maintain confinement integrity for design basis impacts
C1 and/or C2 Areas - 3013 Canister	3013 Canister	Withstand the effects of design basis drops without breaching
	Material Handling Controls	Ensure that the design basis lift height of the 3013 canisters is not exceeded.
C1 and/or C2 Areas - 3013 Transport Cask	3013 Transport Cask	Withstand the effects of design basis drops without release of radioactive material
	Material Handling Controls	Ensure that the design basis lift height of the 3013 transport cask is not exceeded.
C1 and/or C2 Areas - Fuel Rod	None Required	N/A
C1 and/or C2 Areas - MOX Fuel Transport Cask	MOX Fuel Transport Cask	Withstand the effects of design basis drops without release of radioactive material
	Material Handling Controls	Ensure that the design basis lift height of the MOX fuel transport cask is not exceeded.
C1 and/or C2 Areas - Waste Container	None Required	N/A

Table 5.5-16b. Summary of Principal SSCs for Environmental Protection from Load Handling Events (continued)

Event Group	Principal SSC	Safety Function
C1 and/or C2 Areas - Transfer Container	Transfer Container	Withstand the effects of design basis drops without breaching
	Material Handling Controls	Ensure that the design basis lift height of the transfer container is not exceeded.
C1 and/or C2 Areas - Final C4 HEPA Filter	Material Handling Controls	Prevent load handling activities that could potentially lead to a breach in the final C4 HEPA filters.
C4 Confinement	C4 Confinement System	Ensure C4 exhaust is effectively filtered. Maintain a negative glovebox pressure differential between the glovebox and the interfacing systems.
Outside MOX Fuel Fabrication Building	Waste Transfer Line	Ensure that waste transfer line is protected from activities taking place outside the MOX Fuel Fabrication Building.
Facilitywide	MOX Fuel Fabrication Building Structure	Withstand the effects of load drops that could potentially impact radiological material.
	Material Handling Controls	Prevent load handling events that could breach primary confinements.

Table 5.5-17. Summary of Principal SSCs for IOC and Site Worker Protection from Load Handling Events

Event Group	Principal SSC	Safety Function
AP Process Cells	Process Cell Exhaust System	Ensure that a negative pressure exists between the process cell areas and the C2 area. Ensure that process cell exhaust is effectively filtered.
AP/MP C3 Glovebox Areas	C3 Confinement System	Provide filtration to mitigate dispersions from the C3 areas
C1 and/or C2 Areas - 3013 Canister	3013 Canister	Withstand the effects of design basis drops without breaching
	Material Handling Controls	Ensure that the design basis lift height of the 3013 canisters is not exceeded.
C1 and/or C2 Areas - 3013 Transport Cask	3013 Transport Cask	Withstand the effects of design basis drops without release of radioactive material
	Material Handling Controls	Ensure that the design basis lift height of the 3013 transport cask is not exceeded.
C1 and/or C2 Areas - Fuel Rod	None Required	N/A
C1 and/or C2 Areas - MOX Fuel Transport Cask	None Required	N/A
C1 and/or C2 Areas - Waste Container	None Required	N/A
C1 and/or C2 Areas - Transfer Container	Transfer Container	Withstand the effects of design basis drops without breaching
	Material Handling Controls	Ensure that the design basis lift height of the transfer container is not exceeded.
C1 and/or C2 Areas - Final C4 HEPA Filter	Material Handling Controls	Prevent load handling activities that could potentially lead to a breach in the final C4 HEPA filters.
C4 Confinement	C4 Confinement System	Maintain a negative glovebox pressure differential between the glovebox and the interfacing systems. Ensure C4 exhaust is effectively filtered.

Table 5.5-17. Summary of Principal SSCs for IOC and Site Worker Protection from Load Handling Events (continued)

Event Group	Principal SSC	Safety Function
Outside MOX Fuel Fabrication Building	Waste Transfer Line	Ensure that waste transfer line is protected from activities taking place outside the MOX Fuel Fabrication Building.
Facilitywide	MOX Fuel Fabrication Building Structure	Withstand the effects of load drops that could potentially impact radiological material.
	Material Handling Controls	Prevent load handling events that could breach primary confinements.

Table 5.5-18. Explosion Groups and Associated Hazard Assessment Events

Explosion Event Group	Hazard Assessment Event(s)
Hydrogen Explosion	PT-4
Steam Explosion	PT-12
Radiolysis Induced Explosion	AP-6*, AP-41, WH-3
HAN Explosion	AP-8
Hydrogen Peroxide Explosion	AP-37
Solvent Explosion	AP-38
TBP – Nitrate (Red Oils) Explosion	AP-39
AP Vessel Over-Pressurization Explosion	AP-7, AP-20, AP-49, FW-4*, FW-6
Pressure Vessel Over-Pressurization Explosion	FW-3
Hydrazoic Acid Explosion	AP-9
Metal Azide Explosion	AP-44
Pu(VI) Oxalate Explosion	AP-48
Electrolysis Related Explosion	AP-47
Laboratory Explosion	MA-4
Outside Explosion	SF-3*, GH-2, GH-3

* Hazard assessment event with bounding consequences for this event group

Table 5.5-19. Principal SSCs and Associated Safety Functions for all Receptors for the Explosion Event Type

Explosion Group	Principal SSC	Safety Function
Hydrogen Explosion	Process Safety Control Subsystem	Prevent the formation of an explosive mixture of hydrogen within the MFFF facility associated with the use of the hydrogen-argon gas
Steam Explosion	Process Safety Control Subsystem	Ensure isolation of sintering furnace humidifier water flow on high water level.
Radiolysis Induced Explosion	Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels
	Instrument Air System (Scavenging Air)	Provide sufficient scavenging air-flow to dilute the hydrogen produced by radiolysis such that an explosive condition does not occur
	Waste Containers	Ensure that hydrogen buildup in excess of limits does not occur while providing appropriate confinement of radioactive materials
HAN Explosion [Process vessels containing HAN and hydrazine nitrate without NOx addition]	Process Safety Control Subsystem	Ensure the temperature of solutions containing HAN is limited to temperatures within safety limits
	Chemical Safety Control	Ensure that nitric acid, metal impurities, and HAN concentrations are controlled and maintained to within safety limits
HAN Explosion [Vessels containing HAN and no hydrazine nitrate]	Process Safety Control Subsystem	Ensure the temperature of solutions containing HAN is limited to temperatures within safety limits
	Chemical Safety Control	Ensure that nitric acid, metal impurities, and HAN concentrations are controlled and maintained to within safety limits

Table 5.5-19. Principal SSCs and Associated Safety Functions for all Receptors for the Explosion Event Type (continued)

Explosion Group	Principal SSC	Safety Function
HAN Explosion [Process vessels containing HAN and hydrazine nitrate with NO_x addition]	Chemical Safety Control	Ensure concentrations of HAN, hydrazine nitrate, and hydrazoic acid are controlled to within safety limits
	Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels
	Process Safety Control Subsystem	Control the flow rate into the oxidation column
Hydrogen Peroxide	Chemical Safety Control	Ensure that explosive concentrations of hydrogen peroxide do not occur
Solvent Explosion	Process Safety Control Subsystem	Ensure the temperature of solutions containing solvents is limited to temperatures within safety limits
	Process Cell Fire Prevention Features	Ensure that fires in process cells are highly unlikely
	Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels
TBP – Nitrate (Red Oil) Explosion	Offgas Treatment System	Provide an exhaust path for aqueous phase evaporative cooling in process vessels, thereby providing a mechanism for heat removal
		Provide venting of vessels/equipment that potentially contain TBP and its associated by-products to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products
	Process Safety Control Subsystem	Ensure the temperature of solutions containing organic is restricted to temperatures within safety limits in order to limit the rate of energy generation. Ensure that the design basis heatup rate is not exceeded Limit the residence time of organics in process vessels containing oxidizing agents and potentially exposed to high temperatures and in radiation fields

Table 5.5-19. Principal SSCs and Associated Safety Functions for all Receptors for the Explosion Event Type (continued)

Explosion Group	Principal SSC	Safety Function
TBP - Nitrate (Red Oil) Explosion (continued)	Chemical Safety Control	Ensure a diluent is used that does not contain cyclic chain hydrocarbons
AP Vessel Over-Pressurization	Fluid Transport Systems	Ensure that vessels, tanks, and piping are designed to prevent process deviations from creating over-pressurization events
	Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels
	Chemical Safety Control	Ensure control of the chemical makeup of the reagents and ensure segregation/ separation of vessels/components from incompatible chemicals
Pressure Vessel Over-Pressurization	Pressure Vessel Controls	Ensure primary confinements are protected from the impact of pressure vessel failures (bulk gas, breathing air, service air and instrument air systems)
Hydrazoic Acid Explosion	Chemical Safety Control	Ensure the proper concentration of hydrazine nitrate is introduced into the system Ensure that hydrazoic acid is not accumulated in the process or propagated to units that might lead to explosive conditions
	Process Safety Control Subsystem	Ensure the temperature of solutions potentially containing hydrazoic acid is limited to prevent an explosive concentration of hydrazoic acid from developing

Table 5.5-19. Principal SSCs and Associated Safety Functions for all Receptors for the Explosion Event Type (continued)

Explosion Group	Principal SSC	Safety Function
Metal Azide Explosion	Chemical Safety Control	Ensure metal azides are not introduced into high temperature process equipment Ensure the sodium azide has been destroyed prior to the transfer of the alkaline waste into the high alpha waste of the waste recovery unit
	Process Safety Control Subsystem	Ensure the temperature of solutions potentially containing metal azides is insufficient to overcome the activation energy needed to initiate the energetic decomposition of the azide Limit and control conditions under which dry-out can occur
Pu(VI) Oxalate Explosion	Chemical Safety Control	Ensure the valance of the plutonium prior to oxalic acid addition is not VI
Electrolysis-Related Explosion	Process Safety Control Subsystem	Ensure the normality of the nitric acid is sufficiently high to ensure that the offgas is not flammable and to limit excessive hydrogen production
Laboratory Explosions	Chemical Safety Control[c]	Ensure control of the chemical makeup of the reagents and ensure segregation/ separation of vessels/components from incompatible chemicals
	Laboratory Material Controls[c]	Minimize quantities of hazardous chemicals in the laboratory Minimize quantities of radioactive materials in the laboratory
	Facility Worker Action[c]	Ensure that facility workers take proper actions to limit radiological exposure

Table 5.5-19. Principal SSCs and Associated Safety Functions for all Receptors for the Explosion Event Type (continued)

Explosion Group	Principal SSC	Safety Function
Laboratory Explosions (continued)	C3 Confinement System[d]	Provide filtration to mitigate dispersions from the C3 areas
Outside Explosions	Waste Transfer Line	Prevent damage to line from explosions
	MOX Fuel Fabrication Building Structure	Maintain structural integrity and prevent damage to internal SSCs from explosions external to the structure
	Emergency Generator Building Structure	Maintain structural integrity and prevent damage to internal SSCs from explosions external to the structure
	Hazardous Material Delivery Controls	Ensure that the quantity of delivered hazardous material and its proximity to the MOX Fuel Fabrication Building structure, Emergency Generator Building structure, and the waste transfer line are controlled to within the bounds of the values used to demonstrate that the consequences of outside explosions are acceptable.

[a] Note deleted

[b] Note deleted

[c] Required for facility worker only

[d] Required for site worker, environment, and the IOC only

Table 5.5-22. Support System Functions for Principal SSCs (continued)

Principal SSC	Required Support System Principal SSCs	Support System Function
Emergency Control Room Air Conditioning System	Emergency AC Power System	Provide AC power to emergency control room air conditioning system
	Emergency Control System	Provide controls for emergency control room air conditioning system
	Emergency DC Power System	Provide DC power for emergency control room air conditioning system
	Emergency Generator Ventilation System	Provide emergency diesel generator ventilation
Emergency Control System	Emergency AC Power System	Provide AC power to Emergency Control System
	Emergency DC Power System	Provide DC power for the Emergency Control System
	Emergency Diesel Generator Fuel Oil System	Provide emergency diesel generator fuel oil for the emergency diesel generators
	Emergency Generator Ventilation System	Provide emergency diesel generator ventilation
	C3 Confinement System	Provide cooling air exhaust from designated electrical rooms
	Emergency Control Room Air Conditioning System	Provide cooling to maintain appropriate temperature limits for emergency electrical equipment
Emergency DC Power System	Emergency AC Power System	Provide AC power to Emergency DC Power System Battery Chargers
	Emergency Control System	Provide controls for Emergency DC Power System
	Emergency Diesel Generator Fuel Oil System	Provide emergency diesel generator fuel oil for the emergency diesel generators
	Emergency Generator Ventilation System	Provide emergency generator ventilation
Emergency Diesel Generator Fuel Oil Systems	Emergency AC Power System	Provide AC power to Emergency Diesel Generator Fuel Oil System
	Emergency Control System	Provide controls for Emergency Diesel Generator Fuel Oil System
Emergency Generator Building Structure	No Support Systems Required	N/A

Table 5.5-22. Support System Functions for Principal SSCs (continued)

Principal SSC	Required Support System Principal SSCs	Support System Function
Emergency Generator Ventilation System	Emergency AC Power System	Provide AC power to Emergency Generator Ventilation System
	Emergency Control System	Provide controls for Emergency Generator Ventilation System
	Emergency DC Power System	Provide DC power for System to Emergency Generator Ventilation System
Facility Worker Action	No Support Systems Required	N/A
Facility Worker Controls	No Support Systems Required	N/A
Fire Barriers, Detection, and Suppression	(See Chapter 7)	N/A
Fluid Transport Systems	No Support Systems Required	N/A
Glovebox	No Support Systems Required	N/A
Glovebox pressure controls	No Support Systems Required	N/A
Hazardous Material Delivery Controls	No Support Systems Required	N/A
Instrument Air System (Scavenging Air)	No Support Systems Required	N/A
Laboratory Material Controls	No Support Systems Required	N/A
Material Handling Controls	No Support Systems Required	N/A
Material Handling Equipment	No Support Systems Required	N/A
Material Maintenance and Surveillance Programs	No Support Systems Required	N/A
MFFF Tornado Dampers	No Support Systems Required	N/A
Missile Barriers	No Support Systems Required	N/A
MOX Fuel Fabrication Building Structure	No Support Systems Required	N/A
MOX Fuel Transport Cask	No Support Systems Required	N/A
Offgas Treatment System	No Support Systems Required	N/A
Pressure Vessel Controls	No Support Systems Required	N/A
Process Cells	No Support Systems Required	N/A
Process Cell Entry Controls	No Support Systems Required	N/A
Process Cell Fire Prevention Features	No Support Systems Required	N/A
Process Cell Exhaust System	Emergency AC Power System	Provide AC power to Process Cell Exhaust System
	Emergency Control System	Provide controls for Process Cell Exhaust System
	Emergency Diesel Generator Fuel Oil System	Provide emergency diesel generator fuel oil for the emergency diesel generators
	Emergency DC Power System	Provide DC power for High Depressurization Exhaust System
	Emergency Generator Ventilation System	Provide emergency diesel generator ventilation

Table 5.5-22. Support System Functions for Principal SSCs (continued)

Principal SSC	Required Support System Principal SSCs	Support System Function
Process Safety Control Subsystem	Emergency Control System	Shutdown process on loss of power Shutdown and isolate process and systems, as necessary, in response to an earthquake
Seismic Monitoring System and Associated Seismic Isolation Valves	Emergency AC Power System	Provide AC power to Seismic Monitoring System and Seismic Isolation Valves
Sintering Furnace	No Support Systems Required	N/A
Sintering Furnace Pressure Controls	No Support Systems Required	N/A
Supply Air System	No Support Systems Required	N/A
Transfer Containers	No Support Systems Required	N/A
Waste Containers	No Support Systems Required	N/A
Waste Transfer Line	No Support Systems Required	N/A

Table 5.5-23. Mapping of Hazard Assessment Events to Chemical Event Groups

Event Group	General Event Description	Hazard Assessment Events
Events involving only hazardous chemicals not produced from licensed material - Inside Chemical Events	Hazardous chemical (not produced from licensed material)releases from vessels, tanks, pipes, or transport containers internal to the MOX Fuel Fabrication Building	AP-28, AP-30, AP-31, AP-32, AP-33, HV-16, MA-9, MA-10, FW-18 SF-4
Events involving only hazardous chemicals produced from licensed material – Inside Chemical Events	Hazardous chemical (produced from licensed material) releases from pipes and process vessels internal to the MOX Fuel Fabrication Building	AP-45
Events involving only hazardous chemicals - Outside Chemical Events	Hazardous chemical releases from vessels, tanks, pipes, or transport containers external to the MOX Fuel Fabrication Building, primarily from the BRP	SF-2, SF-6, SF-7, SF-8, SF-11, SF-12
Events involving hazardous chemicals and radioactive material	Releases from the AP Process	No mapping required, see other event types

Table 5.5-24. Principal SSCs and their Safety Functions for the Chemical Event Type

Event Group	Principal SSCs	Safety Function
Events involving only hazardous chemicals not produced from licensed material	Emergency Control Room Air Conditioning System	Ensure habitable conditions for operators
Events involving only hazardous chemicals produced from licensed material	Process Cell Entry Controls	Prevent the entry of personnel into process cells during normal operations
		Ensure that workers do not receive a chemical consequence in excess of limits while performing maintenance in the AP process cells
	Facility Worker Action	Ensure that facility workers take proper actions to limit chemical consequences for leaks occurring in C3 ventilated areas
	C4 Confinement System	Contain a chemical release within a glovebox and provide an exhaust path for removal of the chemical vapors
Events involving hazardous chemicals and radioactive material	See SSCs proposed for other event types	N/A
	Process Safety Control Subsystem	Ensure the flow rate of nitrogen dioxide/ dinitrogen tetroxide is limited to the oxidation column of the purification cycle

Table 5.5-25. Low Consequence Screened Hazard Assessment Events

Loss of Confinement Events	Fire Events	Load Handling Events
AP-21	MA-3	FW-16
AP-46	RC-2	RC-11
AS-3		SF-13
AS-4		
FW-7		
FW-8		
FW-12		
GH-14		
HV-3		
HV-4		
HV-6		
HV-10		
HV-11		
RC-6		
RD-4		
RD-5		

Table 5.5-26. Summary of Bounding Mitigated MFFF Event Consequences

Bounding Accident[a]	Maximum Impact to Site Worker (mrem)	Maximum Impact to the IOC (mrem)	Effluent Concentration Ratio
Internal Fire	<100	< 30	<0.2
Load Handling	<150	< 50	<0.2
Hypothetical Explosion Event	<750	< 300	N/A[b]
Hypothetical Criticality Event	<2200	< 900	N/A[b]

[a] The bounding loss of confinement event is bounded by the load handling event provided above.

[b] These event types are prevented by design, hence the effluent concentration ratio (applicable to likely and unlikely events) is not applicable.

Table 5.5-27. Summary of Bounding Low Consequence MFFF Events

Bounding Accident[a]	Maximum Impact to Site Worker (mrem)	Maximum Impact to the IOC (mrem)	Effluent Concentration Ratio
Internal Fire	< 900	< 400	<0.5
Load Handling	<500	< 200	<0.9
Hypothetical Explosion Event[b]	N/A	N/A	N/A
Hypothetical Criticality Event[b]	N/A	N/A	N/A

[a] The bounding loss of confinement event is bounded by the load handling event listed.

[b] There are no bounding unmitigated low consequence events associated with these event types.

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Combustible Loading Controls*	Limit the quantities of combustibles in the filter area to ensure that the C4 final HEPA filters are not adversely impacted by a filter room fire	5.6.2.2
	Limit the quantity of combustibles in fire areas containing a storage glovebox such that any fire that may occur will not encompass a large fraction of the stored radiological material.	
	Limit the quantity of combustibles in a fire area containing 3013 canisters to ensure that the canisters are not adversely impacted by a fire	
	Limit the quantity of combustibles in a fire area containing 3013 transport casks to ensure that the cask design basis fire is not exceeded	
	Limit the quantity of combustibles in a fire area containing fuel rods to ensure that the fuel rods are not adversely impacted by a fire	
	Limit the quantity of combustibles in a fire area containing MOX fuel transport casks to ensure that the cask design basis fire is not exceeded	
	Limit the quantity of combustibles in a fire area containing transfer containers to ensure that the containers are not adversely impacted by a fire	
	Limit the quantity of combustibles in areas containing the pneumatic transfer system to ensure this system is not adversely impacted	
Criticality Control	Prevent criticality events	6.4
Double-Walled Pipe	Prevent leaks from pipes containing process fluids from leaking into C3 areas	11.8.7

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Emergency AC Power System	Provide AC power to emergency DC system battery charger	11.5.7
	Provide AC power to emergency diesel generator fuel oil system	
	Provide AC power to high depressurization exhaust system	
	Provide AC power to C4 confinement system	
	Provide AC power to emergency control room air-conditioning system	
	Provide AC power to emergency diesel generator ventilation system	
	Provide AC power to emergency control system	
	Provide AC power to seismic monitoring system and seismic isolation valves	
	Provide AC power to Process Cell Exhaust System	
Emergency Control Room Air-Conditioning System	Ensure habitable conditions for operators	11.4.11
Emergency Control System	Provide controls for high depressurization exhaust system	11.6.7
	Provide controls for C4 confinement system	
	Provide controls for emergency control room air-conditioning system	
	Provide controls for emergency AC system	
	Provide controls for emergency DC system	
	Provide controls for emergency generator ventilation system	
	Provide controls for emergency diesel generator fuel oil system	
	Shut down process on loss of power	
	Shut down and isolate process and systems, as necessary, in response to an earthquake	
	Provide controls for Process Cell Exhaust System	

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Emergency DC Power System	Provide DC power for high depressurization exhaust system	11.5.7
	Provide DC power for C4 confinement system	
	Provide DC power for emergency AC power system controls	
	Provide DC power for emergency control room air-conditioning system	
	Provide DC power for emergency control system	
	Provide DC power for emergency generator ventilation system	
	Provide DC power to Process Cell Exhaust System	
Emergency Generator Building Structure	Maintain structural integrity and prevent damage to internal SSCs from external fires, external explosions, earthquakes, extreme winds, tornadoes, missiles, rain, and snow and ice loadings	11.1.7
Emergency Generator Ventilation System	Provide emergency diesel generator ventilation	11.4.11
Emergency Diesel Generator Fuel Oil System	Provide emergency diesel generator fuel oil for the emergency diesels	11.5
Facility Worker Action*	Ensure that facility worker takes proper action to limit chemical and radiological exposure	5.6.2.6
Facility Worker Controls*	Ensure that facility workers take proper actions prior to bag-out operations to limit radiological exposure.	5.6.2.9
	Ensure that facility workers take proper actions during maintenance activities to limit radiological exposure.	5.6.2.9
Fire Barriers	Contain fires within a single fire area	7.5.3
Fire Detection and Suppression	Support fire barriers as necessary	7.5.3

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Fluid Transport Systems	Ensure that vessels, tanks, and piping are designed to prevent process deviations from creating over-pressurization events	11.8.7
	Withstand as necessary the effects of the DBE such that confinement of radionuclides is maintained	11.8.7
Glovebox	Maintain confinement integrity for design basis impacts	11.4.11
Glovebox Pressure Controls	Maintain glovebox pressure within design limits	11.4.11
Hazardous Material Delivery Controls*	Ensure that the quantity of delivered hazardous material and its proximity to the MOX Fuel Fabrication Building structure, Emergency Generator Building structure, and the waste transfer line are controlled to within the bounds of the values used to demonstrate that the consequences of outside explosions are acceptable.	5.6.2.8
Instrument Air System (Scavenging Air)	Provide sufficient scavenging airflow to dilute the hydrogen produced by radiolysis such that an explosive condition does not occur	11.9.5
Laboratory Material Controls*	Minimize quantities of hazardous chemicals in the laboratory	5.6.2.7
	Minimize quantities of radioactive materials in the laboratory	5.6.2.7
Maintenance Activity Controls	Isolation of power to the electrolyzer when the electrolyzer is drained	5.6.2.10
Material Handling Controls*	Ensure proper handling of primary confinement types outside of gloveboxes	5.6.2.3
	Ensure that design basis lift heights of primary confinement types (3013 canister, 3013 transport cask, MOX fuel transport cask, and transfer containers) are not exceeded	
	Prevent load handling activities that could potentially lead to a breach in the final C4 HEPA filters	

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Material Handling Controls*	Prevent impacts to the glovebox during normal operations from loads outside or inside the glovebox that could exceed the glovebox design basis	5.6.2.3
	Prevent potential overpressurization of the reusable plutonium oxide cans, due to radiolysis or oxidation of Pu (III) oxalate, and its subsequent impact to the glovebox	
	Prevent load handling events that could breach primary confinements	
Material Handling Equipment	Limit damage to fuel rods/assemblies during handling operations	11.7.7
	Prevent impacts to the glovebox through the use of engineered equipment	
Material Maintenance and Surveillance Programs*	Detect and limit the damage resulting from corrosion	5.6.2.4
MFFF Tornado Dampers	Protect MFFF ventilation systems from differential pressure effects of the tornado	11.4.11
Missile Barriers	Protect MOX Fuel Fabrication Building and Emergency Generator Building internal SSCs from damage caused by tornado- or wind-driven missiles	11.1.7
MOX Fuel Fabrication Building Structure (including vent stack)	Maintain structural integrity and prevent damage to internal SSCs from external fires, external explosions, earthquakes, extreme winds, tornadoes, missiles, rain, and snow and ice loadings	11.1.7
	Withstand the effects of load drops that could potentially impact radiological material	
MOX Fuel Transport Cask	Withstand the design basis fire without breaching	11.4.11
	Withstand the effects of design basis drops without release of radioactive material	
Offgas Treatment System	Provide an exhaust path for the removal of gases in process vessels	11.4.11

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Offgas Treatment System	Provide an exhaust path for aqueous phase evaporative cooling in process vessels, thereby providing a mechanism for heat removal	8.5 and 11.4.11
	Provide venting of vessels/equipment that potentially contain TBP and its associated byproducts to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products	8.5 and 11.4.11
Pressure Vessel Controls*	Ensure that primary confinements are protected from the impact of pressure vessel failures (bulk gas, breathing air, service air, and instrument air systems)	11.9.5
Process Cells	Contain fluid leaks within process cells	11.4.11
Process Cell Entry Controls*	Prevent the entry of personnel into process cells during normal operations	5.6.2.5
	Ensure that workers do not receive a radiological or chemical exposure in excess of limits while performing maintenance in the AP process cells	
Process Cell Fire Prevention Features	Ensure that fires in the process cells are highly unlikely	7.5.3
Process Cell Exhaust System	Effectively filter process cell exhaust	11.4.11
	Operate to ensure that a negative pressure exists between the process cell areas and the C2 areas	
Process Safety Control Subsystem		System design basis provided in 11.6.7. As necessary, basis for parameters provided as shown
	Prevent the formation of an explosive mixture of hydrogen within the MFFF facility associated with the use of the hydrogen-argon gas	8.5
	Ensure isolation of sintering furnace humidifier water flow on high water level	11.4.11 (See Sintering Furnace)
	Ensure the temperature of solutions containing HAN is limited to temperatures within the safety limits	8.5

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Process Safety Control Subsystem (continued)	Control the flowrate into the oxidation column	8.5
	Ensure the temperature of solutions containing organic is restricted to temperatures within safety limits in order to limit the rate of energy generation	8.5
	Limit the residence time of organics in process vessels containing oxidizing agents and potentially exposed to high temperatures and in radiation fields	8.5
	Ensure the temperature of solutions potentially containing hydrazoic acid is limited to prevent an explosive concentration of hydrazoic acid from developing	8.5
	Limit and control conditions under which dry-out can occur	8.5
	Ensure the temperature of solutions potentially containing metal azides is insufficient to overcome the activation energy needed to initiate the energetic decomposition of the azide	8.5
	Ensure the normality of the nitric acid is sufficiently high to ensure that the offgas is not flammable and to limit excessive hydrogen production	8.5
	Warn operators of glovebox pressure discrepancies prior to exceeding differential pressure limits	11.4.11
	Shut down process equipment prior to exceeding temperature safety limits	11.4.11
	Ensure the temperature of solutions containing solvents is limited to temperatures within safety limits	8.5
	Ensure the flow rate of nitrogen dioxide/ dinitrogen tetroxide is limited to the oxidation column of the purification cycle	8.5
	Ensure that the design basis heatup rate is not exceeded	8.5

Table 5.6-1. MFFF Principal SSCs (continued)

Principal SSC	Safety Function	SA Design Basis Reference
Process Safety Control Subsystem (Continued)	Monitor the electrolyzer for faults that could result in arcing or other imparting of electrical energy with the risk of initiation of titanium fire	11.6.7 System Description – 11.3.2.4
Seismic Monitoring System and Associated Seismic Isolation Valves	Prevent fire and criticality as a result of an uncontrolled release of hazardous material and water within the MFFF Building in the event of an earthquake	11.6.7 – for system 11.8.7 – for valves
Sintering Furnace	Provide a primary confinement boundary against leaks into C3 areas	11.4.11
Sintering Furnace Pressure Controls	Maintain sintering furnace pressure within design limits	11.4.11
Supply Air System	Provide unconditioned emergency cooling air to the storage vault and designated electrical rooms	11.4.11
Transfer Container	Withstand the effects of design basis drops without breaching	11.4.11
Waste Containers	Ensure that hydrogen buildup in excess of limits does not occur while providing appropriate confinement of radioactive materials	11.4.11
Waste Transfer Line	Ensure that the waste transfer line is protected from activities taking place outside the MOX Fuel Fabrication Building	10.5
	Prevent damage to the line from external fires, explosions, earthquakes, extreme winds, tornadoes, missiles, rain, and snow and ice loadings	10.5

* Administrative control

Table 5A-1. Unmitigated Event Description - Example

Event Type/ Workshop or Location/ Event Number	Unmitigated Event Description/ Specific Location/ Hazard Sources	Cause
Event type: fire, explosion, dispersion of radioactive material, etc. Applicable Workshop or Support Group: Aqueous Polishing, Powder, Pellet, etc. Alphanumeric event number. Event type designator: E-1 through E-9.	Description of unmitigated event including equipment, effects of event and applicable hazardous materials, without application of principal SSCs. Specific Location: Specific process unit(s) in which event may occur. Mode: Applicable facility operating mode. Normal Operation, Startup, Short Shutdown, Long Shutdown, All Hazard Sources: Hazardous material involved in event, radioactive or hazardous chemical	Event cause

Table 5A-2. Unmitigated Events, Aqueous Polishing

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire Aqueous Polishing AP-1 E-1	A fire involving the AP Calcining Furnace results in an energetic breach of the AP Calcining Furnace Glovebox and the dispersal of radiological materials. Specific Location: AP-Precipitation-Filtration-Oxidation (Calcining Furnace Glovebox) Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in AP Calcining Furnace)	1. Oxygen line leak or break and high temperature ignition source 2. Loss of N2 to furnace bearing.
Internal Fire Aqueous Polishing AP-2 E-1	A solvent fire involving AP Glovebox results in an energetic breach of the AP Glovebox and the dispersal of radiological materials. Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Purification cycle AP-Sampling Mode: All Hazard Sources: Radiological Material (maximum inventory in fire area)	1. Temperature of solvent above flashpoint and ignition source

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire Aqueous Polishing AP-3 E-1	A solvent fire involving AP vessels, tanks and piping in AP Process Cell results in an energetic breach of the AP vessels, tanks and piping and the dispersal of radiological materials. Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Purification cycle AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in AP Process Cell including inventory in AP vessels, tanks and piping)	1. Temperature of solvent above flashpoint and ignition source
Internal Fire Aqueous Polishing AP-4 E-1	A fire involving AP vessels, tanks and piping and combustible material in AP Process Cell results in an energetic breach of the AP vessels, tanks and piping and the dispersal of radiological materials. Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Sampling AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle Mode: All Hazard Sources: Radiological Material (maximum inventory in AP Process Cell including inventory in AP vessels, tanks and piping)	1. Combustible material and ignition source

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire Aqueous Polishing AP-40 E-1	A fire involving combustible materials and a tank containing raffinates in AP Process Cell results in an energetic breach of the AP vessels, tanks and piping and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Purification cycle AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in raffinates tank in AP Process Cell)	1. Combustible material and ignition source
Internal Fire Aqueous Polishing AP-5 E-1	All Internal Fire events for MFFF-Gloveboxes apply to Aqueous Polishing, as far as description and causes are concerned, and are bounding in terms of consequences. (Refer to MFFF Gloveboxes, Events GB-1 and GB-2) Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in AP glovebox)	

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire Aqueous Polishing AP-51 E-1	A titanium fire involving the AP Electrolyzer results in an energetic breach of the AP Electrolyzer and the dispersal of radiological materials. Specific Location: AP-Dissolution AP-Dissolution of chlorinated feed Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in AP Dissolution Units)	1. Maintenance operations (welding) 2. Electrical fault

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Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion Aqueous Polishing AP-6 E-2	Radiolysis induced hydrogen buildup in the vapor space of an AP vessel, tank or piping (in AP process cell or glovebox) results in a hydrogen explosion (given an ignition source), an energetic breach of the AP vessel, tank or piping, and the dispersal of radiological materials. Specific Location: AP-PuO2 Decanning AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Oxalic mother liquors recovery AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessel)	1. Loss of normal dilution air flow 2. Loss of offgas exhaust flow
Explosion Aqueous Polishing AP-41 E-2	Radiolysis induced hydrogen buildup in the vapor space of a raffinates tank (in AP process cell) results in a hydrogen explosion (given an ignition source), an energetic breach of the AP vessel, tank or piping, and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Purification cycle AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in raffinates tank in AP Process Cell)	1. Loss of normal dilution air flow 2. Loss of offgas exhaust flow

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion AP-7 E-2	A process-related chemical over-pressurization involving flammable, explosive, or reactive chemicals in AP vessels, tanks and piping (in AP process cell or glovebox) results in an energetic breach of the AP vessels, tanks and piping and the Dispersal of Nuclear Materials. Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Corrosive chemicals interact with vessels/piping/associated equipment 2. Incorrect chemical handling 3. Incorrect reagent preparation 4. Temperature of chemical(s) above flashpoint 5. Hydrogen or other explosive gas released due to incompatible chemical addition errors 6. Explosive gas and electrical short 7. Explosive gas and unknown ignition source
Explosion Aqueous Polishing AP-8 E-2	A process-related chemical explosion involving HAN/Nitric Acid in AP vessels, tanks and piping (in AP process cell or glovebox) results in an energetic breach of the AP vessels, tanks and piping and the Loss of Confinement / Dispersal of Nuclear Materials. Specific Location: AP-Purification cycle AP-Precipitation-Filtration-Oxidation AP-Solvent Recovery AP-Solvent Waste Reception AP-Acid Recovery AP-Oxalic mother liquors recovery Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Incorrect or excessive chemical addition 2. Incorrect or excessive chemical addition and failure to perform required sampling of AP solutions 3. Incorrect reagent preparation 4. Reagent concentration due to evaporation 5. Explosive gas and electrical short 6. Explosive gas and unknown ignition source

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion Aqueous Polishing AP-9 E-2	A process-related chemical explosion involving hydrazoic acid in AP vessels, tanks and piping (in AP process cell or glovebox) results in an energetic breach of the AP vessels, tanks and piping and the Loss of Confinement / Dispersal of Nuclear Materials. Specific Location: AP-Purification cycle AP-Solvent Waste Reception AP-Solvent Recovery AP-Precipitation-Filtration-Oxidation AP-Off gas treatment AP-Oxalic mother liquors recovery Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Incorrect or excessive chemical addition 2. Incorrect or excessive chemical addition and failure to perform required sampling of AP solutions 3. Incorrect reagent preparation 4. Temperature of chemical(s) above flashpoint 5. Explosive gas and electrical short 6. Explosive gas and unknown ignition source
Explosion Aqueous Polishing AP-20 E-2	Over-pressurization involving AP vessels, tanks and piping (i.e., evaporator or boiler) inside an AP Process Cell results in an energetic breach of the AP vessels, tanks and piping, and the dispersal of radiological materials. Specific Location: AP-Oxalic mother liquors recovery AP-Acid recovery Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in evaporator in AP Process Cell)	1. Control system failure

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion Aqueous Polishing AP-37 E-2	A process-related chemical explosion involving hydrogen peroxide (in AP process cell or glovebox) in AP vessels, tanks and piping results in an energetic breach of the AP vessels, tanks and piping and the Loss of Confinement / Dispersal of Nuclear Materials. Specific Location: AP-Dissolution AP-Dissolution of chlorinated feed Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Human error or equipment failure
Explosion Aqueous Polishing AP-38 E-2	A process-related chemical explosion involving solvents in AP vessels, tanks and piping (in AP process cell or glovebox) results in an energetic breach of the AP vessels, tanks and piping and the Loss of Confinement / Dispersal of Nuclear Materials. Specific Location: AP-Purification cycle AP-Solvent recovery AP-Solvent Waste Reception AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Explosive concentration of solvent vapors in a confined space with an ignition source

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion Aqueous Polishing AP-39 E-2	A process-related chemical explosion involving red oil formation (nitrates or nitric acid solutions of heavy metals and TBP at temperatures in excess of 133 C) in AP boiler, vessel, or tank (in AP process cell or glovebox) results in an energetic breach of the AP boiler, vessel, or tank and the Loss of Confinement / Dispersal of Nuclear Materials. Specific Location: AP-Purification cycle AP-Acid recovery AP-Liquid Waste Reception AP-Precipitation-Filtration-Oxidation AP-Oxalic mother liquors recovery Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Temperature above 133 C in boiler, vessel, or tank and presence of nitrates or nitric acid solutions of heavy metals and TBP
Explosion Aqueous Polishing AP-44 E-2	A process-related chemical explosion involving an azide (other than hydrazoic acid) in an AP boiler, vessel, or tank (in an AP cell or glovebox) results in an energetic breach of the AP boiler, vessel, or tank and the Loss of Confinement / Dispersal of Nuclear Materials. Specific Location: AP-Purification cycle AP-Solvent recovery AP-Solvent Waste Reception AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Temperature above 133 C in boiler, vessel, or tank and presence of azide solutions.

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion Aqueous Polishing AP-47 E-2	Electrolysis-induced hydrogen buildup in the vapor space of an electrolyzer results in a hydrogen explosion and the dispersal of radiological materials. Specific Location: AP-Dissolution AP-Dissolution of chlorinated feed Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Incorrect chemical handling 2. Incorrect reagent preparation 3. Hydrogen or other explosive gas released due to incompatible chemical addition errors 4. Explosive gas and electrical short 5. Explosive gas and unknown ignition source
Explosion Aqueous Polishing AP-48 E-2	A process-related chemical explosion involving plutonium (VI) oxalate in heated equipment in the calcining furnace results in an energetic breach and the dispersal of radiological materials. Specific Location: AP-Precipitation-Filtration-Oxidation AP-Oxalic mother liquors recovery Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Incorrect chemical handling 2. Incorrect reagent preparation 3. Hydrogen or other explosive gas released due to incompatible chemical addition errors 4. Explosive gas and electrical short 5. Explosive gas and unknown ignition source
Explosion Aqueous Polishing AP-49 E-2	A process-related chemical explosion involving liquid addition to the calcining furnace results in an energetic breach of the furnace and glovebox and the dispersal of radiological materials. Specific Location: AP-Precipitation-Filtration-Oxidation Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessels, tanks and piping)	1. Corrosive chemicals interact with vessels/piping/ associated equipment 2. Incorrect chemical handling 3. Incorrect reagent preparation 4. Temperature of chemical(s) above flashpoint 5. Hydrogen or other explosive gas released due to incompatible chemical addition errors 6. Explosive gas and electrical short 7. Explosive gas and unknown ignition source

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-10 E-3	Excessive temperature of AP Calcining Furnace results in high temperature damage to and breach of the AP Calcining Furnace Glovebox and the dispersal of radiological materials. Specific Location: AP-Precipitation-Filtration-Oxidation (Calcining Furnace Glovebox) Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in AP Calcining Furnace Glovebox)	1. Control system failure 2. Loss of cooling of process equipment by glovebox ventilation
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-11 E-3	Excessive temperature of AP Electrolyzer results in high temperature damage to and breach of the AP Electrolyzer and damage to the glovebox panels and the dispersal of radiological materials. Specific Location: AP-Dissolution (Electrolyzer Glovebox) AP-Dissolution of chlorinated feed Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in AP Electrolyzer Glovebox)	1. Control system failure 2. Electric isolation failure 3. Loss of cooling to process equipment

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-12 E-3	Corrosion of an AP Glovebox by corrosive chemicals results in a breach (i.e., material failure) of glovebox confinement and dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in AP glovebox)	1. Corrosive chemicals interact with AP glovebox leading to failure
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-13 E-3	Back-flow from the AP Calcining Furnace through a nitrogen or oxygen supply line to an interfacing system followed by the opening of this interfacing system (during operation or maintenance) results in a breach of glovebox primary confinement and dispersal of radiological materials to areas where workers might be present. Specific Location: AP-Precipitation-Filtration-Oxidation (Calcining Furnace Glovebox) Mode: All Hazard Sources: Radiological Material (maximum inventory in AP Calcining Furnace)	1. Loss of gas flow through the supply line and failure of pipes and valves

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-14 E-3	Back-flow from AP vessels, tanks and piping through a supply line (e.g., compressed air, bubbler transmitter line) to an interfacing system followed by the opening of this interfacing system (during operation or maintenance) results in a breach of primary confinement and dispersal of radiological materials to areas where workers might be present. Specific Location: AP-PuO2 Decanning AP-PuO2 Canning AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle AP-Sampling Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessel, tank or piping)	1. Loss of gas flow through the supply line and failure of pipes and valves

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-16 E-3	A break or leakage in AP vessels, tanks and piping within AP Process Cell results in a breach of confinement, and the dispersal of radiological materials. Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle Mode: All Hazard Sources: Radiological Material (maximum inventory in the effected equipment in AP Process Cell)	1. Corrosion of AP vessels, tanks and piping 2. Mechanical failure of AP vessels, tanks and piping
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-42 E-3	A break or leakage of a raffinates tank in an AP Process Cell results in a breach of confinement, and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Purification cycle AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in raffinates tank in AP Process Cell)	1. Corrosion of raffinates tank 2. Mechanical failure of raffinates tank
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-46 E-3	Excessive temperature (due to decay heat) of PuO2 Buffer Storage Unit (powder storage area). Specific Location: AP-Pre-Polishing Milling Storage Mode: All Hazard Sources: Radiological Material (maximum inventory in buffer storage unit)	1. Loss or blockage of HVAC cooling system 2. Loss of power to HVAC cooling system

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-17 E-3	Back-flow from AP vessels, tanks and piping through a liquid supply line (e.g., steam or condensate lines, acid recovery line, hot water lines) to an interfacing system results in a breach of confinement (i.e., leakage into an interfacing system) and dispersal of radiological materials. Specific Location: AP-Precipitation-Filtration-Oxidation AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP- Sampling Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessel, tank or piping)	1. Loss of liquid flow through the supply line and failure of pipes and valves
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-18 E-3	Back-flow from AP vessels, tanks and piping through a reagent supply line to an interfacing system followed by the opening of this interfacing system (during operation or maintenance) results in a breach of confinement and dispersal of radiological materials to areas where workers might be present. Specific Location: AP-Reagents AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle Mode: All Hazard Sources: Radiological Material (maximum inventory in AP vessel, tank or piping)	1. Loss of gas or liquid flow through the supply line and failure of pipes and valves

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-21 E-3	A loss of exhaust flow involving the Off-Gas Process Confinement System for AP vessels, tanks and piping results in degraded performance of the off-gas system (affecting both AP process cells and AP gloveboxes). Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in single AP vessel)	1. Loss of normal electrical power 2. Mechanical failure of off-gas exhaust fans
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-22 E-3	Internal Flood due to a leak or rupture of cooling water pipes to an AP electrolyzer results in breach of the AP electrolyzer glovebox and the dispersal of radiological materials. Specific Location: AP-Dissolution AP-Dissolution of chlorinated feed Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in AP Electrolyzer Glovebox)	1. Corrosive chemicals interact with cooling water piping

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-23 E-3	All Loss of Confinement / Dispersal of Nuclear Material events for MFFF-Gloveboxes apply to Aqueous Polishing, as far as description and causes are concerned, and are bounding in terms of consequences. (Refer to MFFF Gloveboxes Events GB-3 through GB-7 and GB-11) Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in AP glovebox)	
Loss of Confinement / Dispersal of Nuclear Material Aqueous Polishing AP-50 E-3	A leak outside of a glovebox in piping results in a release of radioactive material inside a room with C-3 ventilation. Specific Location: AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in single AP vessel)	1. Corrosive chemicals interact with piping 2. Mechanical failure of AP piping.

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
External Exposure Aqueous Polishing AP-24 E-4	Operator is inadvertently exposed to excessive direct radiation in Aqueous Polishing resulting in excessive radiation exposure. Specific Location: Aqueous Polishing Mode: All Hazard Sources: Maximum Direct Radiation Source	1. Exposure due to unintended radioactive material buildup 2. Unplanned or unintended access to High Radiation Area 3. Human error or equipment failure
Criticality Aqueous Polishing AP-25 E-5	Re-configuration of fissile material potentially results in nuclear criticality and the release of radiological material. Specific Location: Aqueous Polishing Mode: All Hazard Sources: Fissile and Radiological Material	1. Excessive quantity of fissile material is accumulated in process unit 2. Incorrect sample analysis 3. Inadvertent concentration of process solution 4. Human error or equipment failure 5. Change in geometry of process unit 6. Internal flooding of process unit.
Load Handling Aqueous Polishing AP-36 E-6	A break or leakage in AP vessels, tanks and piping within an AP Glovebox results in a breach of confinement, and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in AP glovebox including inventory in AP vessels, tanks and piping)	1. Human error or equipment failure during load handling operations inside a glovebox

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Load Handling Aqueous Polishing AP-26 E-6	All Load Handling events for MFFF-Gloveboxes apply to Aqueous Polishing, as far as description and causes are concerned, and are bounding in terms of consequences. (Refer to MFFF Gloveboxes Events GB-8 through GB-10) Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	
Load Handling Aqueous Polishing AP-27 E-6	A Load Handling event involving miscellaneous load handling devices and AP vessels, tanks, and piping within an AP Process Cell results in a dispersal of radiological materials. Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle Mode: All Hazard Sources: Radiological Material (maximum inventory in AP Process Cell – dissolution - including inventory in AP vessels, tanks and piping)	1. Human error or equipment failure during maintenance activities

Table 5A-2. Unmitigated Events, Aqueous Polishing (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Load Handling Aqueous Polishing AP-43 E-6	A Load Handling event involving miscellaneous load handling devices and a raffinates tank in an AP Process Cell results in a dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Purification cycle AP-Liquid Waste Reception Mode: All Hazard Sources: Radiological Material (maximum inventory in raffinates tank in AP Process Cell)	1. Human error or equipment failure during maintenance activities
Chemical Aqueous Polishing AP-28 E-7	A chemical release due to fire in a C2 Area (e.g., Reagents rooms) involving flammable or reactive chemicals in AP vessels, tanks and piping results in a chemical release with potential impact on the worker and on control area habitability. Specific Location: AP-Reagents Mode: All Hazard Sources: Hazardous Chemicals	1. Ignition of combustible material by electrical equipment (e.g., spark) 2. Incorrect reagent addition and subsequent reaction 3. Other causes for ignition
Chemical Aqueous Polishing AP-30 E-7	A break or leakage in AP vessels, tanks and piping in C2 Areas results in a chemical release with potential impact on the worker and on control area habitability. Specific Location: AP-Reagents Mode: All Hazard Sources: Hazardous Chemicals	1. Mechanical failure of AP vessels, tanks and piping 2. Corrosive failure of AP vessels, tanks and piping

Table 5A-8. Unmitigated Events, Waste Handling (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Load Handling Waste Handling WH-9 E-6	All Load Handling events for MFFF-Gloveboxes apply to this workshop, as far as description and causes are concerned, and are bounding in terms of consequences. (Refer to MFFF Gloveboxes Events GB-8 through GB-10) Specific Location: Maintenance and Mechanical Dismantling Filter Dismantling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	

Table 5A-9. Unmitigated Events, Miscellaneous Areas

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire MFFF-Miscellaneous Areas) MA-1 E-1	A fire involving combustibles and ignition sources (e.g., transient combustibles, solvents, flammable gases, and electrical equipment, plasma torches, evaporators, furnaces, heating plates) in a laboratory with a Glovebox results in an energetic breach of the Glovebox and the dispersal of radiological materials. Specific Location: Laboratories Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in laboratory glovebox)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Multiple ignition sources
Internal Fire MFFF-Miscellaneous Areas MA-2 E-1	A fire in a C2 Area involving combustibles (e.g., electrical equipment, transient combustibles, HEPA filter) results in a breach of a container of contaminated or radioactive material (i.e., a transfer container) and the dispersal of radiological materials. Specific Location: AP-Solvent Waste Reception AP-Liquid Waste Reception MFFF-Air locks, corridors, stairways, and safe areas Mode: All Hazard Sources: Radiological Material (maximum inventory in container)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Combustibles and unknown ignition source

Table 5A-9. Unmitigated Events, Miscellaneous Areas (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire MFFF-Miscellaneous Areas MA-12 E-1	A fire in a C2 Area involving combustibles (e.g., electrical equipment, transient combustibles, HEPA filter) results in a breach of a container of contaminated or radioactive material (i.e., a waste drum) and the dispersal of radiological materials. Specific Location: AP-Solvent Waste Reception AP-Liquid Waste Reception MFFF-Air locks, corridors, stairways, and safe havens Mode: All Hazard Sources: Radiological Material (maximum inventory in container)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Combustibles and unknown ignition source
Internal Fire MFFF-Miscellaneous Areas MA-3 E-1	A fire (due to electrical equipment, transient combustibles, etc.) affecting miscellaneous areas (e.g., air locks, corridors, stairs, etc.) in a C2 area results in fire damage but no safety related impact. Specific Location: MFFF-Air locks, corridors, stairways, and safe areas MFFF-Storage Areas (non-waste) MFFF-Offices and personal access areas Mode: All Hazard Sources: None	1. Combustibles and electrical short 2. Maintenance activities 3. Combustibles and unknown ignition source

Table 5A-9. Unmitigated Events, Miscellaneous Areas (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion MFFF-Miscellaneous Areas MA-4 E-2	An explosion in a laboratory involving flammable, explosive, or reactive chemicals (e.g., organics or explosive gases) results in the dispersal of radiological material. Specific Location: Laboratories Mode: All Hazard Sources: Radiological Material (maximum inventory in laboratory)	1. Leak or spill of flammable liquids or gasses 2. Chemical reaction releases explosive gasses
Loss of Confinement / Dispersal of Nuclear Material MFFF-Miscellaneous Areas MA-5 E-3	A container of contaminated or radioactive material (i.e., a transfer container or a 3013 container) fails or is damaged while being handled by miscellaneous handling devices in a C2 Area and results in breach of the container and the dispersal of radiological materials. Specific Location: AP-Solvent Waste Reception AP-Liquid Waste Reception MFFF-Airlocks, corridors, and stairways Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in container)	1. Human error or equipment failure during container handling operations
Loss of Confinement / Dispersal of Nuclear Material MFFF-Miscellaneous Areas MA-6 E-3	Corrosion of a laboratory glovebox by corrosive chemicals results in a breach (i.e., material failure) of glovebox confinement and dispersal of radiological materials. Specific Location: Laboratories Mode: All Hazard Sources: Radiological Material (maximum inventory in laboratory glovebox)	1. Corrosive chemicals interact with glovebox leading to failure

Table 5A-9. Unmitigated Events, Miscellaneous Areas (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
External Exposure MFFF-Miscellaneous Areas MA-7 E-4	Operator is inadvertently exposed to excessive direct radiation in the MFFF-Miscellaneous Areas resulting in excessive radiation exposure. Specific Location: Laboratories Mode: All Hazard Sources: Maximum Direct Radiation Source	1. Exposure due to unintended radioactive material buildup 2. Human error or equipment failure
Criticality MFFF-Miscellaneous Areas MA-8 E-5	Re-configuration of fissile material potentially results in nuclear criticality and the release of radiological material. Specific Location: Laboratories Mode: All Hazard Sources: Fissile and Radiological Material	1. Excessive quantity of fissile material is accumulated in process unit 2. Improper placement of fissile material outside of criticality safe storage locations 3. Introduction of moderator (e.g., internal flooding of process unit) 4. Human error or equipment failure
Load Handling MFFF-Miscellaneous Areas MA-11 E-6	A container of contaminated or radioactive material (i.e., a waste drum) fails or is damaged while being handled by miscellaneous handling devices in a C2 Area and results in breach of the container and the dispersal of radiological materials. Specific Location: AP-Solvent Waste Reception AP-Liquid Waste Reception MFFF-Airlocks, corridors, and stairways Mode: Normal Operation Hazard Sources: Radiological Material (maximum inventory in container)	1. Human error or equipment failure during waste drum handling operations

Table 5A-9. Unmitigated Events, Miscellaneous Areas (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Chemical MFFF-Miscellaneous Areas MA-9 E-7	A fire affects the Additives Preparation Area and results in toxic chemicals being released from the chemical containers with potential impact on the worker and on control area habitability. Specific Location: MFFF-Additives Preparation Area Mode: All Hazard Sources: Hazardous Chemicals	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Combustibles and unknown ignition source
Chemical MFFF-Miscellaneous Areas MA-10 E-7	A breach of hazardous chemical containers in the Additives Preparation Area results in a chemical release with potential impact on the worker and on control area habitability. Specific Location: MFFF-Additives Preparation Area Facility Wide Mode: All Hazard Sources: Hazardous Chemicals	1. Human error or equipment failure 2. Corrosion of containers 3. Drop of container(s)

Table 5A-10. Unmitigated Events, Support Facilities Outside MFFF

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire Support Facilities Outside MFFF SF-1 E-1	A fire (involving diesel fuel storage, gas storage platform, the Reagents Processing Building, etc.) occurs and affects the MFFF Building resulting in structural damage. Specific Location: General Plant and Outside Areas Reagents Processing Building Gas Storage Facility Emergency Diesel Generator Building Standby Diesel Generator Building Access Control Building Administration Building Technical Support Building Mode: All Hazard Sources: Radiological Material (maximum inventory in MFFF susceptible to the consequences of external fires or explosions)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Combustibles and unknown ignition source
Internal Fire Support Facilities Outside MFFF SF-2 E-1	A fire (involving electrical equipment, transient combustibles, etc.) affects UO2 drums outside the AP/MP Building (e.g., in the Secured Warehouse Building) and results in a breach of confinement and the dispersal of hazardous materials potentially impacting the control room operator. Specific Location: General Plant and Outside Areas Secured Warehouse Building Mode: All Hazard Sources: Hazardous Material (maximum inventory of UO2 in Secured Warehouse Building)	1. Combustibles and electrical short 2. Combustibles and unknown ignition source

Table 5A-10. Unmitigated Events, Support Facilities Outside MFFF (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Explosion Support Facilities Outside MFFF SF-3 E-2	An explosion at a nearby support facility (e.g., diesel fuel storage, gas storage platform, the Reagents Processing Building, nearby MFFF support facility on the MFFF site) outside the MFFF Building results in structural damage to the MFFF. Specific Location: General Plant and Outside Areas Reagents Processing Building Gas Storage Facility Emergency Diesel Generator Building Standby Diesel Generator Building Access Control Building (Armory) Mode: All Hazard Sources: Radiological Material (maximum inventory in MFFF susceptible to disruption by structural damage)	1. Fuel oil or gas leak combined with electrical short or Combustibles and unknown ignition source 2. Unintended interaction of chemicals which are explosively incompatible 3. Human error or equipment failure
Loss of Confinement / Dispersal of Nuclear Material Support Facilities Outside MFFF SF-14 E-3	A leak or break in an underground waste pipeline outside MFFF results in a breach of confinement, and the dispersal of radiological materials. Specific Location: General Plant and Outside Areas Mode: All Hazard Sources: Radiological Material (maximum inventory of waste tank)	1. Mechanical failure of piping 2. Corrosion induced failure of piping 3. Human error results in pipe break

Table 5A-10. Unmitigated Events, Support Facilities Outside MFFF (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Load Handling Support Facilities Outside MFFF SF-13 E-6	A handling accident, a fire or natural phenomena affects UO2 drums outside the AP/MP Building (e.g., in the Secured Warehouse Building) and results in a breach of confinement and the dispersal of hazardous materials potentially impacting the control room operator. Specific Location: General Plant and Outside Areas Secured Warehouse Building Mode: All Hazard Sources: Hazardous Material (maximum inventory of UO2 in Secured Warehouse Building)	1. Human error or equipment failure during load handling operations 2. Combustibles and electrical short 3. Combustibles and unknown ignition source
Chemical Support Facilities Outside MFFF SF-4 E-7	A diesel fuel oil leak from a diesel fuel tank or associated piping results in a chemical release with potential impact on the worker and on control area habitability. Specific Location: Emergency Diesel Generator Building Standby Diesel Generator Building Mode: All Hazard Sources: Hazardous Chemicals	1. Mechanical failure of fuel tank 2. Inadvertent puncture of fuel tank

Table 5A-10. Unmitigated Events, Support Facilities Outside MFFF (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Chemical Support Facilities Outside MFFF SF-6 E-7	A loss of ventilation in the Reagents Processing Building results in toxic chemicals being released from the vessels, tanks, and piping in the building (but not being ventilated) and potentially impacting the worker and control area habitability. Specific Location: Reagents Processing Building Mode: All Hazard Sources: Hazardous Chemicals	1. Loss of all normal control systems 2. Loss of power 3. Mechanical failure of ventilation system
Chemical Support Facilities Outside MFFF SF-7 E-7	Extreme weather affects the Reagents Processing Building and results in toxic chemicals being released from the vessels, tanks, and piping in the building and potentially impacting the worker and control area habitability. Specific Location: Reagents Processing Building Mode: All Hazard Sources: Hazardous Chemicals	1. Extreme weather

Table 5A-10. Unmitigated Events, Support Facilities Outside MFFF (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Chemical Support Facilities Outside MFFF SF-8 E-7	An external or internal impact affects the Reagents Processing Building and results in toxic chemicals being released from the vessels, tanks, and piping in the building and potentially impacting the worker and control area habitability. Specific Location: Reagents Processing Building Mode: All Hazard Sources: Hazardous Chemicals	1. Human error or equipment failure
Chemical Support Facilities Outside MFFF SF-11 E-7	A pipe break or leak from vessels, tanks, and piping in the Reagents Processing Building results in toxic chemicals being released from the vessels, tanks, and piping and potentially impacts the worker and control area habitability. Specific Location: Reagents Processing Building Mode: All Hazard Sources: Hazardous Chemicals	1. Mechanical failure of vessels, tanks, or piping
Chemical Support Facilities Outside MFFF SF-12 E-7	A loss of tank venting in vessels, tanks and piping in the Reagents Processing Building results in a chemical release with potential impact on the worker and on control area habitability. Specific Location: Reagents Processing Building Mode: All Hazard Sources: Hazardous Chemicals	1. Mechanical failure of ventilation system

Table 5A-11. Unmitigated Events, HVAC Systems

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire MFFF-HVAC Systems HV-1 E-1	A fire in the C4 VHD System (i.e., C4 Dynamic Confinement) disables the system or damages the HEPA filters and results in a loss of negative pressure in the gloveboxes, breach of confinement, and dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Mode: All Hazard Sources: Radiological Material (maximum inventory in HEPA filters and maximum inventory airborne in the gloveboxes)	1. Combustibles and electrical short circuit 2. Other causes for ignition of combustible material

Table 5A-11. Unmitigated Events, HVAC Systems (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire MFFF-HVAC Systems HV-17 E-1	A fire in the AP Process Offgas System disables the system or damages the HEPA filters and results in a loss of negative pressure in the AP pipes and vessels, breach of confinement, and dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-Precipitation-Filtration-Oxidation AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Oxalic mother liquors recovery AP-Liquid waste reception AP-Off gas treatment AP-Reagents Mode: All Hazard Sources: Radiological Material (maximum inventory in HEPA filters and maximum inventory airborne in the AP pipes and vessels)	1. Combustibles and electrical short circuit 2. Other causes for ignition of combustible material

Table 5A-11. Unmitigated Events, HVAC Systems (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire MFFF-HVAC Systems HV-2 E-1	A fire in the C3 HVAC System (i.e., C3 Dynamic Confinement), the C2 HVAC System, or the Process Cell Ventilation System involving electrical equipment disables the system or damages the HEPA filters and results in a breach of confinement, and dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Process Off-Gas Treatment AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Mode: All Hazard Sources: Radiological Material (maximum inventory in C3 HVAC System)	1. Combustibles and electrical short circuit 2. Other causes for ignition of combustible material

Table 5A-11. Unmitigated Events, HVAC Systems (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-HVAC Systems HV-3 E-3	A loss of negative pressure or a flow perturbation involving the C3 Dynamic Confinement results in a ventilation air flow reversal into a C2 Area. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Mode: All Hazard Sources: Radiological Material	1. Loss of all normal control systems 2. Loss of power 3. Mechanical failure of ventilation system

Table 5A-11. Unmitigated Events, HVAC Systems (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-HVAC Systems HV-4 E-3	A loss of negative pressure or a flow perturbation involving the Process Cells HVAC results in a ventilation air flow reversal into a C2 Area. Specific Location: AP-Solvent recovery AP-Solvent Waste Reception AP-Oxalic mother liquors recovery AP-Off gas treatment AP-Liquid waste reception AP-Dissolution AP-Dissolution of chlorinated feed AP-Acid recovery AP-Purification cycle Mode: All Hazard Sources: Radiological Material (maximum airborne inventory in AP Process Cell not including inventory in AP vessels, tanks and piping)	1. Loss of all normal control systems 2. Loss of power 3. Mechanical failure of ventilation system

Table 5A-11. Unmitigated Events, HVAC Systems (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-HVAC Systems HV-5 E-3	A loss of negative pressure or a flow perturbation involving the C4 Dynamic Confinement results in a ventilation air flow reversal into a C3 Area. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Mode: All Hazard Sources: Radiological Material (maximum airborne inventory in all connected gloveboxes)	1. Loss of normal control system 2. Loss of all power 3. Mechanical failure of ventilation system

Table 5A-11. Unmitigated Events, HVAC Systems (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-HVAC Systems HV-6 E-3	Back-flow from a glovebox room through a C3 ventilation system supply duct to another glovebox room results in a breach of C3 ventilation system confinement and cross contamination of MP and AP ventilation systems. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-PuO2 Canning AP-Recanning AP-Pre-polishing Milling AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Mode: All Hazard Sources: Radiological Material (maximum inventory in C3 area outside of gloveboxes)	1. Loss of air flow through a C3 ventilation system supply duct
Loss of Confinement / Dispersal of Nuclear Material MFFF-HVAC Systems HV-10 E-3	A loss of negative pressure or a flow perturbation involving the C2 Dynamic Confinement results in a ventilation air flow reversal into adjacent areas and contamination of those areas. Specific Location: AP-Reagents MFFF-Miscellaneous Areas Assembly Workshop Cladding and Rod Control Workshop Mode: All Hazard Sources: Radiological Material (maximum unconfined inventory in C2 Areas)	1. Loss of all normal control systems 2. Loss of power 3. Mechanical failure of ventilation system

Table 5A-12. Unmitigated Events, Gloveboxes

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire MFFF-Gloveboxes GB-1 E-1	A fire involving glovebox combustibles (e.g., electrical equipment, transient combustibles, flammable liquids, HEPA filter) results in a breach of the Glovebox and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in a fire area)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Ignition of flammable liquid (e.g., isopropanol used in rod cleaning) 3. Maintenance activities 4. Combustibles and unknown ignition source 5. Spontaneous heating of UO_2/PuO_2.

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire MFFF-Gloveboxes GB-2 E-1	A transfer container (containing contaminated process equipment or contaminated HEPA filters) is involved in a fire and is damaged while outside a glovebox and results in the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in waste container)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Combustibles and unknown ignition source

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-Gloveboxes GB-3 E-3	Over-pressurization of the glovebox (i.e., C4 Dynamic Confinement) by rupture of a high flow or high pressure supply line or by HEPA filter clogging results in a ventilation air flow reversal into a C3 Area. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	1. Rupture of a high flow or high pressure supply line 2. Clogged outlet HEPA filter

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-Gloveboxes GB-4 E-3	Failure of a glove during normal operation or maintenance results in a breach of glovebox confinement and dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	1. Human error results in glove failure during normal operation or maintenance 2. Equipment failure

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-Gloveboxes GB-5 E-3	Back-flow from glovebox through interfacing gas line (e.g., nitrogen, helium) to interfacing system followed by the opening of this interfacing system (during operation or maintenance) results in a breach of glovebox primary confinement and dispersal of radiological materials to areas where workers might be present. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	1. Loss of gas flow through the supply line

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-Gloveboxes GB-6 E-3	Excessive temperature of process equipment inside a glovebox results in high temperature damage to and breach of the glovebox and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	1. Failure of process control system 2. Loss of cooling to process equipment

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-Gloveboxes GB-7 E-3	A plastic bag (containing contaminated process equipment or contaminated HEPA filters) fails or is damaged while being handled outside a glovebox and results in the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in waste container)	1. Human error or equipment failure during load handling operations outside a glovebox

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Loss of Confinement / Dispersal of Nuclear Material MFFF-Gloveboxes GB-11 E-3	A transfer container (containing contaminated process equipment or contaminated HEPA filters) fails or is damaged while being handled outside a glovebox and results in the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in waste container)	1. Human error or equipment failure during load handling operations outside a glovebox

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Load Handling MFFF-Gloveboxes GB-8 E-6	A container handling accident within a glovebox (e.g., a container impact with the glovebox) results in a breach of the container and the glovebox, and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	1. Human error or equipment failure during load handling operations inside a glovebox

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Load Handling MFFF-Gloveboxes GB-9 E-6	A Load Handling Event involving miscellaneous load handling devices outside a glovebox results in a breach of the glovebox, and the dispersal of radiological materials. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery AP-Liquid Waste Reception Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	1. Human error or equipment failure during load handling operations outside a glovebox

Table 5A-12. Unmitigated Events, Gloveboxes (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Load Handling MFFF-Gloveboxes GB-10 E-6	A container handling accident or container failure within a glovebox (i.e., a leak, break, or spill) results in a breach of the container, and the dispersal of radiological materials within the glovebox. Specific Location: AP-Acid recovery AP-Solvent recovery AP-Solvent Waste Reception AP-PuO2 Decanning AP-Recanning AP-Pre-polishing Milling AP-PuO2 Canning AP-Precipitation-Filtration-Oxidation AP-Homogenization-Sampling AP-Dissolution AP-Dissolution of chlorinated feed AP-Purification cycle AP-Sampling AP-Oxalic mother liquors recovery Receiving Workshop Powder Workshop Pellet Workshop Cladding and Rod Control Workshop Miscellaneous Areas (Laboratories) Waste Handling Mode: All Hazard Sources: Radiological Material (maximum inventory in glovebox)	1. Human error or equipment failure during load handling operations inside a glovebox

Table 5A-13. Unmitigated Events, Facility Wide

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
Internal Fire Facility Wide FW-1 E-1	A facility wide fire (due to electrical equipment, transient combustibles, etc.) involves the MFFF Building and results in a breach of confinement, and the dispersal of radiological material. Specific Location: All Process Units and Support Units with radioactive material present Mode: All Hazard Sources: Radiological Material (maximum inventory in MFFF susceptible to a facility wide fire)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Combustibles and unknown ignition source
Internal Fire Facility Wide FW-2 E-1	A fire (due to electrical equipment, transient combustibles, etc.) involves the Pneumatic Pipe Automatic Transfer System and results in a breach of confinement, and the dispersal of radiological material. Specific Location: Facility Wide (Two pneumatic transfer systems) Mode: All Hazard Sources: Radiological Material (maximum inventory in Pneumatic Pipe Automatic Transfer System)	1. Combustibles and electrical short 2. Combustion of waste from exposure to chemicals 3. Maintenance activities 4. Combustibles and unknown ignition source

Table 5A-14. Unmitigated Events, General Hazard

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
External Event (Industrial and Transport Infrastructure Accidents) General Hazard GH-2 E-8	A transportation accident (fire or explosion) outside the MFFF Building results in structural damage to the MFFF or negatively impacts control area habitability. Specific Location: Outside AP/MP Building Mode: All Hazard Sources: Radiological Material (maximum inventory in MFFF susceptible to disruption by structural damage)	1. Transportation accident
External Event (Industrial and Transport Infrastructure Accidents) General Hazard GH-3 E-8	A fire or explosion at a nearby facility outside the MFFF Building (e.g., other SRS facility, Pit Disassembly and Conversion Facility, etc.) results in structural damage to the MFFF or negatively impacts control area habitability. Specific Location: Outside AP/MP Building Mode: All Hazard Sources: Radiological Material (maximum inventory in MFFF susceptible to disruption by structural damage)	1. Human error or equipment failure
External Event General Hazard GH-13 E-8	A fire (involving other nearby facilities, nearby vegetation, or vehicles) occurs and affects the MFFF Building resulting in structural damage. Specific Location: General Plant and Outside Areas Mode: All Hazard Sources: Radiological Material (maximum inventory in MFFF susceptible to the consequences of external fires or explosions)	1. Forrest fire 2. Nearby vehicle fire 3. Combustibles and unknown ignition source at nearby facility

Table 5A-14. Unmitigated Events, General Hazard (continued)

Event Type/Workshop or Location/ Event Number	Unmitigated Event Description/Specific Location/Hazard Sources	Cause
External Event General Hazard GH-14 E-8	A container spill occurs within the MFFF site boundary resulting in the dispersal of radioactive material. Specific Location: Outside Areas Mode: Transportation Hazard Sources: Radiological Material (maximum inventory in MFFF susceptible to the consequences of a spill).	1. Vehicular accident

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LIST OF ACRONYMS AND ABBREVIATIONS (continued)

EC	effluent concentration
ECR	Engineering Change Request
EDMS	Electronic Data Management System
EDST	Eastern Daylight Savings Time
EIS	Environmental Impact Statement
EMMH	external man-made hazard
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration
ERPG	Emergency Response Planning Guidelines
ES&H	Environment, Safety, and Health
ETF	Effluent Treatment Facility
FA	flame acceleration
FEM	finite element model
FEMA	failure modes and effect analysis
FHA	Fire Hazard Analysis
FIC	final isotopic composition
FM	Factory Mutual
FOCI	foreign ownership, control, or influence
fpm	feet per minute
ft	foot
g	gram
g	acceleration due to gravity
gal	gallon
gpm	gallons per minute
GSA	General Separations Area
GSAR	Generic Safety Analysis Report
GSG	geological, seismological, geotechnical
ha	hectare
HAN	hydroxylamine nitrate
HAZOP	hazards and operability study
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
HEPA	high-efficiency particulate air
HFE	human factors engineering
HIS	Human-system interface
HLW	high-level waste
HP	Health Physics
HPLC	high performance liquid chromatography
hr	hour
HVAC	heating, ventilation, and air conditioning
Hz	hertz
I&C	instrumentation and control
I/O	input/output

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

IAEA	International Atomic Energy Agency
ICBO	International Conference of Building Officials
ICP-MS	inductive coupled plasma – mass spectroscopy
ID	identification
IDLH	Immediately Dangerous to Life and Health
IEEE	Institute of Electrical and Electronic Engineers
IOC	Individual Outside the MFFF Controlled Area
in	inch
INES	International Nuclear Event Scale
IROFS	items relied on for safety
ISA	Integrated Safety Analysis
IT/SF	Interim Treatment/Storage Facility
ITP	In-Tank Precipitation Facility
ka	kilo annum or thousands of years
kg	kilogram
kip	kilopound
km	kilometer
kV	kilovolt
L	liter
lb	pound
LDE	Lens of the Eye Dose Equivalent
LETF	Liquid Effluent Treatment Facility
LFL	lower flammable limit
LLC	Limited Liability Company
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LOC	level of severity or concern
LPF	leak path factor
LWR	light water reactor
m	meter
M	molar
M&O	Maintenance and Operations
m^3	cubic meter
Ma	mega annum or millions of years
MACCS2	MELCOR Accident Consequence Code System for the Calculation of the Health and Economic Consequences of Accidental Atmospheric Radiological Releases
MAR	material at risk
mb	body wave magnitude
mbar	millibar
MBP	monobutyl phosphate
MC&A	Material Control and Accounting
MCC	motor control center
MCNP	Monte Carlo N-Particle
MD	duration magnitude

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10. Where moderation control is required for subcriticality, a description of the approach to designing the facility to meet both fire safety and criticality safety requirements (including presence and type of fire suppression).

6.5 DESIGN BASES FOR NON-PRINCIPAL SSCs

As discussed in Chapter 14, an NRC-approved Emergency Plan is not expected to be required for the MFFF. Nonetheless, MFFF operations will comply with the guidance (shall statements) and recommendations (should statements) of ANSI/ANS-8.23-1997, *Nuclear Criticality Accident Emergency Planning and Response*, without exception. While not considered part of the design basis of principal SSCs, this standard provides guidance for minimizing risks to personnel during emergency response to a nuclear criticality accident outside reactors.
Criticality accident emergency planning and response, while an important programmatic element, is not part of the safety basis.

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8. CHEMICAL PROCESS SAFETY

This chapter presents the preliminary chemical process safety assessment for the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF). It describes the chemical processes, major chemicals affecting licensed material and hazardous chemicals produced from licensed material, chemical accident sequences and consequences, process safety information, and safety interfaces.

The preliminary chemical process safety evaluation provides reasonable assurance that the MFFF design provides adequate protection against chemical and radiochemical hazards related to the storage, handling, and processing of licensed material as required by 10 CFR Part 70. The preliminary analyses conducted to date indicate that no additional principal structures, systems, and components (SSCs) are required that are not already identified for control of radiological or other hazards, except as noted in Section 5.5.2.10.6.3. Further chemical process safety evaluation will be performed as part of the detailed design and will be included in the Integrated Safety Analysis (ISA) Summary submitted with the license application for possession and use of special nuclear material (SNM).

8.1 CHEMICAL PROCESS DESCRIPTION

The MOX Fuel Fabrication Building and the Reagent Processing Building form the core group of buildings for plutonium polishing (i.e., aqueous polishing [AP] process) and MOX fuel fabrication (i.e., MOX processing [MP] process). The MOX Fuel Fabrication Building is a multifunctional reinforced-concrete structure containing all of the SNM handling, processing, and fuel fabrication operations. The building is comprised of three major functional, interrelated areas: the MP Area, the AP Area, and the Shipping and Receiving Area. The entire structure and the three component areas are designed for natural phenomena hazards (e.g., earthquakes, floods, tornadoes), as well as potential industrial-type accidents (e.g., load drop, fire) that could impact licensed materials. The Reagent Processing Building, located adjacent to the AP Area of the MOX Fuel Fabrication Building, provides space for storage and mixing of the chemical reagents used in the AP process. Chapter 11 provides detailed descriptions of the MFFF facilities and processes.

8.1.1 Chemical Process Summary

To meet commercial fuel purity specifications, a solvent extraction process is used to separate plutonium from gallium, americium, uranium, and other minor impurities. Polished plutonium oxide (PuO_2) is used to produce MOX fuel. Chemical processes take place as part of the AP and MP processes, supported by chemical preparation in the Reagent Processing Building.

8.1.1.1 Reagent Processing Building

No radioactive materials or radiochemicals are stored, processed, or commingled in the Reagent Processing Building. The floor level of the Reagent Processing Building is slightly above grade and the building has a below-grade collection tank room that receives waste chemicals from the building. The Reagent Processing Building is divided into discrete rooms/areas to segregate chemicals and the associated equipment and vessels to prevent inadvertent chemical interaction. Safety showers and eyewash stations are provided at various locations throughout the facility in accordance with applicable OSHA standards. A loading dock at one end of the Reagent

Processing Building is used for unloading and transfer of chemical containers into and out of the building. Waste chemicals (included those resulting from spills) originating from the Reagent Processing Building are pumped from segregated waste collection tanks to portable containers for proper disposal in accordance with applicable requirements.

Most reagents (e.g., nitric acid, hydrogen peroxide, hydroxylamine nitrate [HAN], hydrazine hydrate, oxalic acid, sodium carbonate, diluent [C10-C13 isoalkane], nitrogen tetroxide, sodium hydroxide, zirconium nitrate, and tributyl phosphate [TBP]) are stored and solutions are prepared in the Reagent Processing Building for use in the AP Area. Nitrates of silver, aluminum, and manganese are stored and prepared in the AP Area. Liquid chemical containers are located inside curbed areas to contain accidental spills. Chemicals are transferred to the AP Area from the Reagent Processing Building via piping located in a concrete, below-grade trench between the two buildings.

Potential impacts of chemical accidents in the Reagent Processing Building on principal SSCs or personnel performing functions related to items relied on for safety (IROFS) are discussed in Chapter 5.

8.1.1.2 Aqueous Polishing Process

The AP process consists of 16 process units or systems (units symbols are indicated in parenthesis):

- Decanning Unit (KDA)
- Milling Unit (KDM)
- Recanning Unit (KDR)
- Dissolution Unit (KDB)
- Dechlorination and Dissolution Unit (KDD)
- Purification Cycle (KPA)
- Solvent Recovery Cycle (KPB)
- Oxalic Precipitation and Oxidation Unit (KCA)
- Homogenization Unit (KCB)
- Canning Unit (KCC)
- Oxalic Mother Liquor Recovery Unit (KCD)
- Acid Recovery Unit (KPC)
- Offgas Treatment Unit (KWG)
- Liquid Waste Reception Unit (KWD)
- Waste Organic Solvent (KWS)
- Automatic Sampling System (KPG).

The AP process is described in detail in Section 11.3.

8.1.1.3 MOX Fuel Fabrication Process

The MP process involves dry workshops (e.g., powder, pellet, and rod processing) and is described in detail in Section 11.2.

8.1.1.4 Laboratory

Chemical and physical analyses of samples from the MP and AP Areas are conducted in the laboratory. Analyses are required for manufacturing control, nuclear material management, quality control, and safety controls. Production sample analyses are performed at different stations consisting of gloveboxes, and transfers between stations are conducted manually (using a specific container or a vial in a vinyl double sleeve) or pneumatically. Several laboratory benches and fume hoods are provided for checking and distributing chemical reagents for different analytical processes. The laboratory is described in further detail in Section 11.11.

8.1.2 Chemical Process Detail

This section addresses the chemical process descriptions, the names and formulae of chemical reactants and products, and operating conditions. This section also identifies which chemicals come in contact with licensed materials, could impact operations with licensed materials, or are formed as by-products from chemical reactions with licensed materials. (Note that "hazardous chemicals produced from licensed materials," as defined in 10 CFR 70, do not include substances prior to process addition to licensed material or after process separation from licensed material.) The chemical process description at this stage of the design includes sufficient information to allow an understanding of the hazards associated with the chemical process.

8.1.2.1 Reagent Chemicals Process

Chemicals are received in various forms (solid, liquid, and gas) for use in the MFFF process. Most chemicals are stored in the Reagent Processing Building while some are stored in the AP Area or the MP Area. The various chemicals prepared and/or stored in these areas include the following:

- Solids
    - Reagent Processing Building – oxalic acid and sodium carbonate
    - AP Area – silver nitrate, sodium sulfite, and plutonium dioxide
    - MP Area – azodicarbonamide, zinc stearate, plutonium dioxide, and uranium dioxide
- Liquids
    - Reagent Processing Building – hydrazine hydrate, hydroxylamine nitrate (HAN), nitric acid (HNO_3), tributyl phosphate (TBP), diluent (C10-C13 isoalkane), hydrogen peroxide, sodium hydroxide, hydrazine nitrate, silver nitrate, sodium carbonate, sodium sulfite, and zirconium nitrate
    - AP Area – recovered nitric acid, aluminum nitrate solution, silver nitrate solution, manganese nitrate solution, diluent, HAN, hydrogen peroxide, oxalic acid, sodium carbonate, sodium hydroxide, sodium nitrite, sodium sulfite, TBP, uranyl nitrate and zirconium nitrate solution
    - MP Area - Isopropanol
- Gases
    - Reagent Processing Building – dinitrogen tetroxide (N_2O_4) (stored in liquefied form)
    - Site – nitrogen, oxygen, hydrogen, argon, P10 (10% methane/90% argon), helium, and 95% argon/5% hydrogen
    - AP Area – nitrogen, oxygen, P10 (10% methane/90% argon), and 95% argon/5% hydrogen

- MP Area – nitrogen, hydrogen, argon, P10 (10% methane/90% argon), helium, and 95% argon/5% hydrogen.

Storage facilities in the Reagent Processing Building contain the following:

- Drums/tote tanks of the following reagents: 13.6N nitric acid, TBP, diluent, HAN (1.9M), hydrazine hydrate (22% hydrazine in water), hydrazine nitrate (30% solution in water), sodium hydroxide (10N)
- Cylinders of liquid dinitrogen tetroxide
- Containers of hydrogen peroxide (30 wt %)
- Storage of material for dissolving solid reagents, including oxalic acid, silver nitrate, sodium sulfite, and sodium carbonate.

Tables 8-1a through 8-1e identify the expected chemicals received and distributed to the MFFF process. Chemicals and chemical mixtures in the process generally are used at lower concentrations than the reagent-grade chemicals stored in the Reagent Processing Building or AP Area.

8.1.2.2 Aqueous Polishing Area Chemical Process

Details on the chemical processes found in the AP area are provided in Section 11.3.

8.1.2.3 MOX Processing Area Chemical Process

The chemical processes in the MP area require the blending of uranium and plutonium oxides and the addition of poreformer and lubricant. Details on the MP Area chemical process are provided in Section 11.2.

8.1.3 Process Chemistry

The descriptive equations and other process chemistry information are provided in Section 11.3.

8.1.4 Chemical Process Equipment, Piping, and Instrumentation

Principal SSCs associated with chemical processing are identified in Chapter 5.

8.1.5 Chemical Process Inventories

The chemical inventory information in Tables 8-2a through 8-2d provides a summary of anticipated onsite inventories. Additional information associated with chemical inventories is provided in Section 11.3.

Common hazardous materials (e.g., vehicle fuel) and commonly used small quantities of solvents and gases are also used onsite. Specific inventories will be identified in the detailed design.

8.1.6 Chemical Process Ranges and Limits

Process ranges and limits are discussed in Section 11.3.

requirements. Non-routine work safety will be addressed through the use of work authorization and task analysis or activity-based hazard analysis.

8.3.1 Chemical Accident Sequence Bases

To identify the physical processes that control the nature and rate of vapor generation and release, a range of initial conditions is considered, as well as the failure modes of storage containers and associated systems. The following release scenarios are addressed:

- Leaks and ruptures involving equipment vessels and piping
- Evaporating pools formed by spills and tank failures
- Flashing and evaporating liquefied gases from pressurized storage.

Explosion events that could result in the release of hazardous chemical vapors are addressed in Sections 5.5 and 8.5. The chemical consequences are based on bounding analyses. More detailed accident sequences will be developed in the ISA as necessary.

8.3.2 Unmitigated Sequences

In lieu of a mechanistic calculation of the release, a conservative bounding release model is used to determine the consequences to the site worker (100 meters) and to the IOC (160 meters). Releases are modeled to occur using the total material at risk from the largest single tank or container. Furthermore, no credit is afforded to process equipment installed to remove/scrub some of the potentially released chemicals prior to release from the MFFF.

8.3.3 Estimated Concentrations

Estimates of hazardous chemical concentrations include techniques, assumptions, and models that are consistent with industry practice, are verified and/or validated, and follow the guidance on atmospheric and consequence modeling found in NUREG/CR-6410, *Nuclear Fuel Cycle Accident Analysis Handbook.*

Several different methodologies were applied to the performance of chemical consequence analyses based on the nature of the chemical and the location of the receptor. For calculating airborne concentrations at the CAB involving evaporative releases, the more conservative release rate from the following two separate evaporation models (Kawamura and Mackay 1987, equation 8.3-1 and NUREG/CR-6410, Appendix B, equation 8.3-2) was used. These evaporation models, applicable to liquids released at ground level in a pool, are as follows:

$$E=A*K_M*(MW_m * P_v/(R*T)) \qquad (8.3\text{-}1)$$

where
E = evaporation rate (kg/sec)
A = area of the evaporating puddle (m^2)
K_M = mass transfer coefficient (m/sec)

MW_m = molecular weight of the material of interest (kg/kmol)
P_v = vapor pressure (Pa)
R = the gas constant (8314 J/kmol K)
T = ambient temperature (K)

$$Q_o = k_g * A_p * p_v * M / (R * T_p) \qquad (8.3\text{-}2)$$

where
Q_o = rate of evaporation (kg/sec)
k_g = mass transfer coefficient (m/sec)
A_p = area of the pool (m^2)
p_v = vapor pressure (Pa)
M = molecular weight of the material of interest (kg/kmol)
R = the gas constant (8314 J/kmol K)
T_p = temperature of the pool (K)

The mass transfer coefficient is dependent on the air speed over the pool or puddle. Unmitigated releases are assumed to occur outdoors. For the unmitigated releases, an air speed of 2.2 meters/second is used, which is consistent with 95% "worst-case" meteorological conditions at SRS. For a mitigated release inside the MFFF, the air speed is calculated from the air flow rate through the room in which the pool or puddle is located and the minimal vertical cross-sectional area of the room.

To calculate airborne concentrations at the CAB for other chemicals with low solute concentrations or low vapor pressures, source terms were generated using a five-factor formula involving the product of the material at risk (MAR), damage ratio (DR), airborne release fraction (ARF), respirable fraction (RF), and leak path factor (LPF). These values were then multiplied by the CAB atmospheric dispersion factor (χ/Q) calculated by the ARCON96 (Code System to Calculate Atmospheric Relative Concentrations in Building Wakes) code to obtain an airborne concentration at the CAB.

For evaporative releases affecting the site worker, the more conservative release rate from the two separate evaporation models identified above was selected and multiplied by the 100-meter atmospheric dispersion factor (χ/Q) calculated by the ARCON96 code to obtain an airborne concentration. To calculate airborne concentrations for other chemicals affecting the site worker, source terms were generated using the same five-factor formula described above. These values were then multiplied by the 100-meter atmospheric dispersion factor (χ/Q) from the ARCON96 code. For chlorine and NO_x releases, release rates were obtained from chemical flow balances for the units where these chemicals are generated from SNM. The applied release rates do not credit the process scrubbers installed to remove a majority of these chemical by-products.

8.3.3.1 Dispersion Modeling

The dispersion model in the ARCON96 code is the preferred model for distances close to the release point (e.g., 100 or 160 meters). ARCON96 empirically accounts for building wake effects occurring under all meteorological conditions and plume meander, which occurs during light-wind stable conditions. It is the only model that is available that accounts for both the vertical and horizontal components of building wake effects and the effects of plume meander. Plume meander occurs under very stable light wind speed conditions (e.g., F stability class with wind speed of 2.2 meters/second). The magnitude of plume meander decreases with distance from the release, higher wind speeds, and more unstable conditions. All of the meander factor decays within 1 kilometer. The building wake effect also decays as the distance from the release location increases, but it increases with wind speed and more unstable conditions. The faster the wind speed, the larger the aerodynamic effect on the wind field of the building structure.

8.3.4 Concentration Limits

Chemical concentration limits are required to be established to evaluate the potential consequences to the IOC and to workers for an accidental release of chemicals. Three levels, High (H), Intermediate (I), and Low (L), based on 10 CFR §70.61, are used to define these limits.

Limits are based on Acute Exposure Guideline Level (AEGL) values and Emergency Response Planning Guideline (ERPG) values. Since AEGL and ERPG values are not established for all MFFF chemicals, Temporary Emergency Exposure Limits (TEELs) have been adopted for use in chemical consequence analysis. TEELs were adopted by the U.S. Department of Energy (DOE) Subcommittee on Consequence Assessment and Protective Action (SCAPA). The SCAPA-approved methodology was used to obtain hierarchy-derived TEELs.

The original TEEL methodology used only hierarchies of published concentration limits (i.e., Permissible Exposure Levels [PELs] or Threshold Limit Values – Time-Weighted Averages [TLV-TWAs], Short-Term Exposure Levels [STELs], and Immediately Dangerous to Life and Health [IDLH] values) to provide estimated values approximating ERPGs. The expanded method for deriving TEELs also includes published toxicity data (TD_{LO}, TC_{LO}, LD_{50}, LC_{50}, LD_{LO}, and LC_{LO}). Hierarchy-based values take precedence over toxicity-based values, and human toxicity is preferred to animal toxicity data. Subsequently, default assumptions based on statistical correlation of ERPGs at different levels (e.g., ratios of ERPG-3s to ERPG-2s) were used to calculate TEELs where there were gaps in the data. The TEEL hierarchy/toxicity methodology was used to develop community exposure limits for over 1,200 chemicals to date. The following are the TEEL definitions:

- TEEL-0 – The threshold concentration below which most people will experience no appreciable risk of health effects.
- TEEL-1 – The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
- TEEL-2 – The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
- TEEL-3 – The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

TEEL values for MFFF chemicals are listed in Table 8-5.

As identified in Section 11.4.2.7.4, each emergency control room air intake is continuously monitored for hazardous chemicals. Monitoring will be performed for those chemicals whose unmitigated release could result in control room concentrations above the limits specified in Table 8-5a. The preferred limit is the IDLH value for a chemical as reported by the National Institute of Occupational Safety and Health. If a TEEL-3 value is less than an IDLH value for a given chemical, the TEEL-3 limit will be applied. For a chemical with no IDLH value, a TEEL-2 limit will be applied. Table 8-5a contains all the chemical limits used for the control room consequence assessment and provides the source for the specified limits.

Emergency actions will be initiated prior to reaching the chemical consequence concentration limits. Specific set-points will be determined during final design.

Chemical consequence categories for comparison to 10 CFR §70.61 are provided in Table 8-6.

8.4 CHEMICAL ACCIDENT CONSEQUENCES

8.4.1 Analysis

Consequence analysis follows the guidance found in NUREG/CR-6410. Conservatism is embedded in the source term and the ground-level release models.

The analysis to determine the effects to the IOC is based on the following assumptions:

- A ground level release (conservative);
- No mechanical or buoyancy plume rise (conservative);

- Neutrally buoyant gas model (conservative).

These bounding assumptions envelop uncertainties inherent in realistic analyses.

Data in Tables 8-2a through 8-2d were used to perform chemical consequence analyses associated with the largest credible unmitigated spill or loss of containment accident involving each of these chemicals. Airborne concentrations were calculated at distances correlating to the site worker (100 meters) and the IOC (160 meters). These concentrations were then compared to the TEELs presented in Table 8-5. From this comparison, a consequence category was established (low, intermediate, high) using the guidance outlined in Table 8-6. These consequence categories correspond to those identified in 10 CFR §70.61.

It should be noted that for the chemicals identified in Tables 8-2a through 8-2d whose onsite inventory is not yet established or is based on preliminary data, the analysis is based on a conservative projection for that chemical. Nonhazardous chemicals and gases identified in Table 8-2d were not evaluated. Except for oxygen, exposure to these gases poses an asphyxiant hazard only. Gas concentrations at asphyxiation levels are not credible at the distances corresponding to the CAB. Gas concentrations at asphyxiation levels may be credible for very large leaks at the distance corresponding to the site worker. Oxygen has no established toxicity limit.

Results of the chemical consequences calculation indicate that for all chemicals to which the requirements of 10 CFR §70.61 apply, unmitigated consequence categories fall within the acceptable range for site workers and the IOC, with the exception of those releases described in Section 5.5.2.10.6.3. Thus, no principal SSCs are required for the protection of site workers and the IOC, except as identified in Section 5.5.2.10.6.3.

Nitric acid leaks or spills in the Aqueous Polishing area of the MFFF were also modeled at temperatures up to the boiling point of nitric acid. The evaporation rate of the nitric acid was calculated using airspeeds determined from the air flow rate through the room and the minimal vertical cross-sectional area of the room. The consequences of these nitric acid leaks or spills over the full range of temperatures were calculated to be low for the site worker and the IOC.

For the facility worker, the chemical consequences are estimated to be low, except as identified in Section 5.5.2.10. Calculations will be performed for the ISA to confirm this estimate. Principal SSCs have been defined for radiological events, and these SSCs are expected to be applicable to process units where chemicals mix with radiological material, except as identified in Section 5.5.2.10. Furthermore, for chemical exposures that could affect the facility worker in performing a required safety function in the Emergency Control Room, the Emergency Control Room Air Conditioning System is identified as a principal SSC (see Section 5.5.2.10). In the unlikely event that the ISA performed as part of detailed design identifies events that are not bounded, additional SSCs will be identified to ensure that chemical risks are acceptable.

8.4.2 Latent Impacts

There are no residual, long-term impacts to facility workers, site workers or the IOC that could result from an acute chemical exposure to licensed material or hazardous chemicals produced from licensed material. There are only two "potential carcinogens" at MFFF (i.e., chemicals on the list of "potential carcinogens"). The two chemicals are hydrazine and uranium (soluble and insoluble). Plutonium and other radionuclides may have carcinogenic effects; however, plutonium and other radionuclides are addressed in section 5.5.

For evaluating site workers exposed to a chemical release, the calculated concentration of an airborne chemical at 100 meters is compared to a TEEL-2 value. For evaluating the IOC exposed to a chemical release, the calculated concentration of an airborne chemical at the controlled area boundary is compared to a TEEL-1 value.

The TEEL determination process considers latent health effects (i.e., cancer). The determination process (for TEEL-2 and TEEL-3 values) selects hierarchy-based values first, if available, followed by toxicity-based values. TEEL-2 values are based on Emergency Response Planning Guideline (ERPG-2) values when available, or on Permissible Exposure Limits (PEL), Threshold Limit Values (TLV), or Recommended Exposure Limit (REL) ceiling (C) values, or on 5 x TLV-Time Weighted Average (TWA) values, in order of availability, followed by toxicity-based values. TEEL-2 values, along with ERPG, PEL, TLV, or REL ceiling (C) values, take into account latent health effects (i.e., cancer) where appropriate. TEEL-3 values are based on Emergency Response Planning Guideline (ERPG-3) values when available or on Immediately Dangerous to Life and Health (IDLH) values, in order of availability, followed by toxicity-based values. Since the ERPG committee considers latent health effects, TEEL-3 values also take into account latent health effects (i.e., cancer) where appropriate. TEEL-1 values are less than or equal to TEEL-2 values and ensure that exposures do not result in latent health effects.

Therefore, by using the TEEL values as limits, the chemical consequence analysis has taken into account latent health effects (i.e., cancer) from the two potential carcinogens at MFFF.

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gravitational forces producing convection in this phase. Downward heat transfer between the phases, therefore, involves conduction, rather than convection, and heat removal is consequently lower. This description represents the limiting system from the perspective of selecting a minimum initiation temperature for a runaway reaction.

DCS has selected a design basis steam temperature of 133 °C to limit the heat generation rate. In addition, a design basis bulk fluid temperature of 125 °C has been selected. Furthermore, DCS has implemented a design basis heatup rate of a maximum of 2 °C/min after startup. This design basis temperature is based on the experimentally determined minimum initiation temperature for a *closed* system and is derived from isothermal experimental conditions. Furthermore, selection of this design basis temperature ensures that the selected diluent (discussed below) will not undergo degradation and lower the minimum initiation temperature of a runaway reaction.

Experimental evidence suggests that diluents containing a large fraction of cyclic hydrocarbons (i.e., ~20 - 30% naphthenes) undergo significant nitration at temperatures lower than corresponding systems composed of both TBP and diluent. Therefore, the nature of the diluent is relevant in establishing the temperature at which systems composed of TBP/diluent begin to "run away." The use of C_{10}-C_{13} branched chain hydrocarbons (aliphatic diluent HPT) in the AP process optimizes both the plutonium decontamination factor and the nitration resistance to ensure an adequate safety margin associated with the operation of the process. Consequently, DCS has identified the properties of the diluent as the safety function of the chemical safety control principal SSC. The design basis for this chemical safety control principal SSC is to utilize a diluent that does not contain cyclic chain hydrocarbons.

DCS has also identified the offgas treatment system as a principal SSC. The safety function of the offgas treatment system is to provide venting of vessels/equipment that may potentially contain TBP and its associated by-products to prevent over-pressurization in the case of excessive oxidation of TBP and/or its degradation products. The design basis value for this principal SSC is selected to be consistent with experimental results (e.g., 8×10^{-3} mm^2/g of organic). The use of venting implies control of the bulk quantity of organics that may be present in a given vessel. However, for the majority of vessels DCS has limited the volume of the vessel so as to not require this limitation (i.e., tanks are considered full of organics and hence, no limitation of organic content is necessary). Note that as an additional protection feature, DCS has implemented the following features to preclude the transfer of bulk quantities of organic to heated equipment:

- A diluent washing pulsed column for washing the extracted plutonium aqueous stream
- A diluent washing pulsed column for washing the extraction process unloaded feeding solution ("raffinates stream")
- A diluent washing mixer-settler for washing the extracted uranium aqueous stream
- A diluent washing mixer-settler for washing the aqueous phase containing TBP degradation products from solvent recovery.

In those few cases where the vent area to mass ratio is not satisfied, the offgas treatment system is still credited as a principal SSC. However, in this case the safety function of this principal SSC is to provide an exhaust path for aqueous phase evaporative cooling in process vessels, thereby providing a mechanism for heat removal. This implies that the required venting for mass transfer is much less than that required for pressure relief during a "runaway" reaction. This principal SSC is utilized in conjunction with the process safety control subsystem to ensure that the rate of energy generation does not exceed the rate of heat removal. Thus, the design basis of the offgas treatment system for this case is to relieve 1.2 times the combination of energy generation and energy input to the system. This safety function of the offgas treatment system is the primary means for satisfying the performance requirements of 10 CFR 70.61.

In addition, because gases are released during the chemical reactions, foaming may be possible. Foaming in the organic phase occurs as self-heating accelerates due to the gases generated. Significant amounts of foam could limit the effectiveness of the vent. In addition, foam can be thermally isolated from the rest of the system because of its insulating qualities. A foaming mass that is undergoing an exothermic reaction may therefore attain a higher temperature than a liquid in contact with a heat sink, such as water. When a cyclic diluent was utilized in past red oil incidents, foaming is believed to have occurred prior to a runaway condition. Again, the selection of a diluent containing no cyclic hydrocarbons and limitations on the temperature are implemented as principal SSCs to limit foaming and provide reasonable assurance that the vents remain effective.

8.5.1.5.6 Impact of Tomsk-7 Event

On April 6, 1993, at the Tomsk-7 nuclear fuel processing facility located in Siberia, Russia, there purportedly were two sequential explosions that caused physical damage to the facility and contaminated the facility and the surrounding area. The explosions appear to be due to the "red oil" phenomenon associated with nitric acid, TBP, and the hydrocarbon diluent used by the Russians, and was initiated by actions that constituted violations to operating procedures and operating conditions unlikely to occur at the MFFF. Inadequate venting was also a likely contributor in the explosion.

The Tomsk-7 event identified a new mechanism to the TBP degradation/red oil formation phenomenon. This arose from the apparent initiation of an energetic runaway reaction in the vicinity of 90°C, far below the previously observed minimum temperature for a runaway TBP hydrolysis-limited reaction. Several investigators postulated that the accumulation of two degradation products, butanol and butyl nitrate, may have been responsible for the lower initiation temperature. Experimental results have verified that these two degradation products of TBP can, in the presence of concentrated nitric acid, release significant energy at temperatures far less than 133°C. Significant buildup of degraded organics is not expected at the MFFF (i.e., solvent is routinely used and regenerated as part of normal operations, and most degraded organics are destroyed during normal operation). Nonetheless, such a buildup is conservatively postulated.

Butanol, a TBP degradation product, is rapidly and completely converted to butyl nitrate at temperatures of 110°C to 120°C, and is oxidized further to butyric acid, propionic acid, and acetic acid when contacted with moderate to strong (6M to 15.8M) nitric acid. Butyl nitrate oxidation begins as solutions with 10M to 15.8M nitric acid are heated to between 52°C and 85°C, and these reactions are strongly exothermic. The heat of reaction for butanol oxidation has been determined to be -466 cal/g (-1948 J/g) of butanol based on a 1:1 butanol to nitric acid the Pu/U concentration in process vessels in which this condition could exist is very low. Furthermore, the production of hydrazoic acid which may be formed in the process via CAR Equation 8.5-7 is limited by the quantity of nitrous acid that is available to react with the hydrazine to form hydrazoic acid, which could potentially form uranium or plutonium azides. In addition, the hydrazoic acid that may be present in the system is distributed between the organic and aqueous phases further limiting the quantity of uranium and plutonium azide that may be produced. The quantity of nitrous acid present in the system is limited by the moderate temperatures, controlled with principal SSCs, as described in Section 8.5.1.8, and the low acidity, approximately 1 N HNO_3.

Silver Azide (AgN_3)

Contact of hydrazoic acid with silver nitrate in the process can form silver azide salts in accordance with the following:

$$HN_3 + AgNO_3 \rightarrow AgN_3 + HNO_3 \qquad (8.5\text{-}15)$$

The initial silver concentration upstream of the Purification Cycle is approximately 0.011 mol/L. TBP liquid/liquid extraction operates with a decontamination factor for silver of approximately 2×10^5. No silver has ever been detected downstream of the extraction step in operating installations at the Cogema UP3 facility, based on mass spectrometry detection threshold for silver of 9.3×10^{-9} mol/L. The silver nitrate concentration reaching the "Pu stripping" (PULS3000) and "Pu barrier" (MIXS4000) purification steps can therefore be assumed to be less than 5.5×10^{-8} mol/L ($0.011/2 \times 10^5$) under anticipated conditions.

The credited principal SSC required to meet the performance requirements of 10 CFR §70.61 is the Process Safety Control Subsystem, which ensures the temperatures in process vessels that may potentially contain hydrazoic acid are maintained below 140°C, which is below the thermal decomposition temperature of silver azide.

As described above, the presence of silver azide is limited to equipment within the Purification Cycle downstream of the plutonium stripping pulse column (PULS3000). This limitation on the location of the silver azide is attributed to a process that destroys azides and hydrazoic acid that may have formed in the Purification Cycle and Solvent Recovery unit. As previously stated, sampling controls which have been identified as a principal SSC confirm the effectiveness of the destruction of both azides and hydrazoic acid prior to transfers of solutions for processing by downstream units.

Sodium Azide (NaN_3)

Sodium azide results from the reaction between sodium cations and azide anions as follows:

$$2HN_3 + Na_2CO_3 \rightarrow 2NaN_3 + H_2CO_3 \qquad (8.5\text{-}16)$$

$$HN_3 + NaOH \rightarrow NaN_3 + H_2O \qquad (8.5\text{-}17)$$

In the Solvent Recovery unit, sodium (in the form of sodium carbonate and sodium hydroxide) is added to the solvent washing mixer-settler (MIXS1000). This sodium reacts with the hydrazoic acid formed in the Purification Cycle producing sodium azide. The maximum concentration of azide in the system is 0.058 M Thus, as in nitric acid media, the solubility of sodium azide is approximately 6.3 M at 25°C, the minimum concentration of sodium needed for sodium azide to precipitate would be 684 M ($[Na^+][N_3^-] = 6.3^2$), i.e., 342 M of Na_2CO_3. Such value cannot be reached as the solubility of Na_2CO_3 in water at 25°C is equal to 4 M, so that the concentration of sodium azide formed as a result of the neutralization reactions is limited within safety requirements. Consequently, no additional safety controls are required.

To limit the propagation of the sodium azide within the AP process, DCS will incorporate a process to destroy the sodium azide. This process relies on the addition of sodium nitrite followed by acidification.

As previously discussed, the sampling principal SSC will ensure the effectiveness of the process to destroy sodium azide. This destruction is necessary prior to the introduction of the waste stream containing the sodium azide into acidified solutions due to the possible liberation of hydrazoic acid from the solution which is possible if the normality of the solution is in excess of 0.426 M nitric acid.

8.5.1.10 Nitrogen Dioxide/Dinitrogen Tetroxide

Dinitrogen tetroxide is stored in cylinders in the Reagents Processing Building in liquefied form. Service air is injected into the cylinder to transfer the liquid into an electric boiler, also located in the Reagents Processing Building, where it is vaporized to gaseous nitrogen dioxide and other NOx gases prior to entry into the aqueous polishing area.

Under normal operations, the vaporized gases are reacted with the hydrazine, HAN, and hydrazoic acid that are present with plutonium nitrate in the oxidation column (CLMN6000) of the purification cycle of the Aqueous Polishing process. If these gases or the unreacted nitrogen dioxide/dinitrogen tetroxide gases are released from the stack the consequences to all potential receptors are acceptable (no offgas treatment is required).

However, if the process fails (e.g., the flow of plutonium nitrate with hydrazine, HAN, and hydrazoic acid is deterministically assumed to be abnormally terminated to the oxidation column) and/or the nitrogen dioxide/dinitrogen tetroxide supplied to the oxidation column flows at an abnormally high rate, then there is the potential for chemical consequences associated with the release of these gases that may have come into contact with licensed materials to be unacceptable to the site worker. As described in section 5.5.2.10, the flow of nitrogen dioxide/dinitrogen tetroxide is limited to the oxidation column such that chemical consequences to the site worker are acceptable. The design basis value is the TEEL-2 limit for nitrogen dioxide/dinitrogen tetroxide listed in Table 8-5. This is the value that will not be exceeded during normal and off-normal conditions. To exceed this value, preliminary calculations indicate a flow rate in excess of approximately 44 kg/hr is necessary. The normal flow rate is approximately 0.92 kg/hr. Calculations will be performed as part of detailed design (and

Table 8-1a. Process Chemicals in the Reagent Processing Building (BRP)

CHEMICAL			
Name	**Formula**	**CAS Number (Note 3)**	**STATE**
Diluent (C10-C13 Isoalkanes)	C10-C13 Isoalkanes	68551-17-7	Liquid
Hydrazine Monohydrate	$N_2H_4.H_2O$	7803-57-8	Liquid
Hydrazine Nitrate (Note 1)	$N_2H_4\text{-}HNO_3$	13464-97-6	Liquid
Hydrogen Peroxide	H_2O_2	7722-84-1	Liquid
Hydroxylamine Nitrate	$NH_2OH\text{-}HNO_3$	13465-08-2	Liquid
Nitric Acid	HNO_3	7697-37-2	Liquid
Nitrogen Dioxide (Note 2)	NO_2	10102-44-0	Gas
Dinitrogen Tetroxide	N_2O_4	10544-72-6	Liquid/ Gas
Oxalic Acid	$H_2C_2O_4$	144-62-7	Solid/ Liquid
Silver Nitrate	$AgNO_3$	7761-88-8	Solid/ Liquid
Sodium Carbonate	Na_2CO_3	497-19-8	Solid/ Liquid
Sodium Hydroxide	NaOH	1310-73-2	Liquid
Sodium Sulfite	Na_2SO_3	7757-83-7	Liquid
Tributyl Phosphate	$(C_4H_9)_3PO_4$	126-73-8	Liquid
Zirconium Nitrate	$Zr(NO_3)_2 *5H_2O$	13746-89-9	Liquid

Table 8-1a Notes:

1. Hydrazine nitrate is made up in the BRP from hydrazine hydrate and nitric acid.
2. Nitrogen dioxide is the coexisting dimer of nitrogen tetroxide in gas form.
3. CAS Number refers to Chemical Abstract Services Registry Number.

Table 8-1b. Process Chemicals in the Aqueous Polishing Building (BAP)

CHEMICAL			
Name	**Formula**	**CAS Number**	**STATE**
Aluminum Nitrate	$Al(NO_3)_3*9H_2O$	13473-90-0	Liquid
Chlorine (Note 1)	Cl_2	7782-50-5	Gas
Diluent (C10-C13 Isoalkanes)	C10-C13 Isoalkanes	68551-17-7	Liquid
Hydrazine Nitrate	N_2H_4-H NO_3	13464-97-6	Liquid
Hydrogen Peroxide	H_2O_2	7722-84-1	Liquid
Hydroxylamine Nitrate	NH_2OH-HNO_3	13465-08-2	Liquid
Manganese Nitrate	$Mn(NO_3)_2$	10377-66-9	Solid/ Liquid
Nitric Acid	HNO_3	7697-37-2	Liquid
Nitric Oxide (Note 1)	NO	10102-43-9	Gas
Nitrogen Dioxide	NO_2	10102-44-0	Gas
Nitrogen Oxides (Note 1)	NO_x	N/A	Gas
Oxalic Acid	$H_2C_2O_4$	144-62-7	Solid/ Liquid
Plutonium Dioxide	PuO_2	N/A	Solid
Plutonium Oxalate (Note 2)	$Pu(C_2O_4)_2$	N/A	Solid/Liquid
Plutonium Nitrate (Note 2)	$Pu(NO_3)_3$, $Pu(NO_3)_4$, $PuO_2(NO_3)_2$	N/A	Liquid
Silver Nitrate	$AgNO_3$	7761-88-8	Solid/ Liquid
Sodium Carbonate	Na_2CO_3	497-19-8	Solid/ Liquid
Sodium Hydroxide	NaOH	1310-73-2	Liquid
Sodium Sulfite	Na_2SO_3	7757-83-7	Solid/ Liquid
Tributyl Phosphate	$(C_4H_9)_3PO_4$	126-73-8	Liquid
Uranium Dioxide	UO_2	1344-59-8	Solid
Uranyl Nitrate (Note 2)	$UO_2(NO_3)_2$	36478-76-9	Liquid
Zirconium Nitrate	$Zr(NO_3)_2*5H_2O$	13746-89-9	Liquid

Table 8-1b Notes:

1. Chlorine and nitrogen oxides are by-products of AP processing.
2. Plutonium oxalate, plutonium nitrate, and uranyl nitrate are intermediate products of AP processing.

Table 8-1c. Process Chemicals in the MOX Processing Building (BMP)

CHEMICAL			
Name	**Formula**	**CAS Number**	**STATE**
Azodicarbonamide	$H_2NCONNCONH_2$	123-77-3	Solid
Isopropanol	C_3H_7OH	67-63-0	Liquid
Plutonium Dioxide	PuO_2	N/A	Solid
Uranium Dioxide	UO_2	1344-59-8	Solid
Zinc Stearate	$Zn(C_{18}H_{35}O_2)_2$	557-05-1	Solid

Table 8-1d. Process Chemicals in the Laboratories

CHEMICAL			
Name	Formula	CAS Number	STATE
Aluminum Nitrate	$Al(NO_3)_3*9H_2O$	13473-90-0	Liquid
Argon-Hydrogen	95% Ar; 5% H_2	N/A	Gas
Argon-Methane (P10)	90% Ar; 10% CH_4	N/A	Gas
Chromic (III) Acid	CrO_3	7738-94-5	Liquid
Ferrous sulfate	$FeSO_4$	7720-78-7	Liquid
Fluorine	F	7782-41-4	Liquid
Hydrofluoric Acid	HF	7664-39-3	Liquid
Hydrochloric Acid	HCl	7647-01-0	Liquid
Iron	Fe	7439-89-6	Liquid
Manganous Sulfate	$MnSO_4$	7785-87-7	Liquid
Potassium Permanganate	$KMnO_4$	7722-64-7	Liquid
Silver Oxide	AgO	20667-12-3	Liquid
Sodium	Na	7440-23-5	Liquid
Sodium Nitrite	$NaNO_2$	7632-00-0	Liquid
Sulfuric Acid	H_2SO_4	7664-93-9	Liquid
Sulfamic Acid	HSO_3NH_2	5329-14-6	Liquid
Thenoyl TrifluoroAcetone	$C_8H_5F_3O_2S$	326-91-0	Liquid
Xylene	$C_6H_4(CH_3)_2$	1330-20-7	Liquid

Table 8-1e. Process Gases in the Gas Storage Area (GSA)

CHEMICAL			
Name	Formula	CAS Number	STATE
Argon	Ar	7440-37-1	Liquid/ Gas
Argon-Hydrogen	95% Ar; 5% H_2	N/A	Gas
Argon-Methane (P10)	90% Ar; 10% CH_4	N/A	Gas
Helium	He	7440-59-7	Gas
Hydrogen	H_2	1333-74-0	Gas
Nitrogen	N_2	7727-37-9	Gas
Oxygen	O_2	N/A	Gas

Table 8-2a. Chemicals and Chemical Tanks or Containers in the BRP, BAP, and BMP

Chemical	Form	Symbol, Usage	Concentration		BRP		BAP		BMP
			Quantity[3]	Units	Tank	Capacity (gal, U.N.O.)	Tank	Capacity (gal, U.N.O.)	Capacity
Aluminum Nitrate	L	$Al(NO_3)_3 \cdot 9H_2O$	1	g(Al)/l	N/A	N/A	RAN-TK1480	6	N/A
Azodicarbonamide	S	poreformer	100	%	N/A	N/A	N/A	N/A	1.2-kg (bag)
	S	poreformer	100	%	N/A	N/A	N/A	N/A	4-L (hopper)
Diluent (Note 1)	L	diluent	100	%	Tote Tank	180	N/A	N/A	N/A
	L	TBP + diluent	70	%	N/A	N/A	RTP-TK1020	30	N/A
	L	diluent	100	%	RDO-TK1000	80	RDO-TK1005	50	N/A
Hydrazine Monohydrate and Hydrazine Nitrate	L	N_2H_4-(H_2O)	35	%	Tote Tank	126	N/A	N/A	N/A
	L	N_2H_4-H_2O	35	%	RHZ-TK1150	80	N/A	N/A	N/A
	L	N_2H_4-HNO_3	4	M	RHZ-REV1160	15	N/A	N/A	N/A
	L	N_2H_4-HNO_3	4	M	RHZ-REV1170	15	N/A	N/A	N/A
	L	N_2H_4-HNO_3	4	M	RHZ-REV1180	30	N/A	N/A	N/A
	L	N_2H_4-HNO_3	4	M	RHZ-TK1181	5	N/A	N/A	N/A
Hydrazine and Sodium Hydroxide	L	N_2H_4-NaOH	0.16	N	RHZ-TK1182	384	RHZ-TK1183	384	N/A
Hydrogen Peroxide	L	H_2O_2	35	%	Drums	TBD	N/A	N/A	N/A
	L	H_2O_2	10	%	RHP-TK1200	40	RHP-TK1205	40	N/A

Table 8-2a. Chemicals and Chemical Tanks or Containers in the BRP, BAP, and BMP (continued)

Chemical	Form	Symbol, Usage	Concentration		BRP		BAP		BMP
			Quantity[3]	Units	Tank	Capacity (gal, U.N.O.)	Tank	Capacity (gal, U.N.O.)	Capacity
Hydroxylamine Nitrate	L	HAN	1.9	M	Tote Tank	180	N/A	N/A	N/A
	L	HAN	1.9	M	RHN-TK1060	200	RHN-TK1090	55	N/A
Hydroxylamine Nitrate and Hydrazine	L	HAN-N_2H_2-HNO_3	0.15	M	RHN-TK1070	627	RHN-TK1080	320	N/A
	L	HAN-N_2H_4- HNO_3	0.15	M	N/A	N/A	RHN-TK1081	5	N/A
	L	HAN-N_2H_4- HNO_3	0.15	M	RHN-TK1110	150 Note 2	RHN-TK1082	60 Note 2	N/A
Isopropanol	L	$(CH_3)_2CHOH$	100	%	N/A	N/A	N/A	N/A	0.5-L (bottle)
Manganese Nitrate	L	Mn^{+2}	1	%	N/A	N/A	Bottles	TBD	N/A
	L	HNO_3-Mn^{+2}	0.01	M	N/A	N/A	RMN-TK1050	15	N/A
	L	HNO_3-Mn^{+2}	0.01	M	N/A	N/A	RMN-TK1051	5	N/A
	L	HNO_3-Mn^{+2}	0.011	M	N/A	N/A	KCD-TK4000	100 liters	N/A
	L	HNO_3-Mn^{+2}	0.011	M	N/A	N/A	KCD-TK4100	100 liters	N/A
	L	HNO_3-Mn^{+2}	0.011	M	N/A	N/A	KCD-TK4200	100 liters	N/A
	L	HNO_3-Mn^{+2}	9.90E-05	M	N/A	N/A	KCD-TK1000	1000 liters	N/A
	L	HNO_3-Mn^{+2}	9.90E-05	M	N/A	N/A	KCD-TK1500	1000 liters	N/A
	L	HNO_3-Mn^{+2}	9.90E-05	M	N/A	N/A	KCD-TK2000	1000 liters	N/A
Nitric Acid (Note 1)	L	HNO_3	13.6	N	Tote Tank	126	N/A	N/A	N/A

Table 8-2a. Chemicals and Chemical Tanks or Containers in the BRP, BAP, and BMP (continued)

Chemical	Form	Symbol, Usage	Concentration		BRP		BAP		BMP
			Quantity[3]	Units	Tank	Capacity (gal, U.N.O.)	Tank	Capacity (gal, U.N.O.)	Capacity
	L	HNO_3	13.6	N	RNA-TK1260	142	RNA-TK1265	161	N/A
	L	HNO_3	13.6	N	RNA-TK1261	5	N/A	N/A	N/A
	L	HNO_3	13.6	N	N/A	N/A	RNA-TK1262	5	N/A
	L	HNO_3	13.6	N	N/A	N/A	RNA-TK1263	5	N/A
	L	HNO_3	13.6	N	N/A	N/A	KDD-TK1500	60 liters	N/A
	L	HNO_3	13.6	N	N/A	N/A	KDD-TK2500	60 liters	N/A
	L	HNO_3	13.6	N	N/A	N/A	KPC-TK4000	500 liters	N/A
	L	HNO_3	13.6	N	N/A	N/A	KPC-TK4500	500 liters	N/A
	L	HNO_3	6	N	N/A	N/A	RNA-TK1330	8	N/A
	L	HNO_3	2.1	N	N/A	N/A	KPC-TK1000	5000 liters	
	L	HNO_3	1.5	N	N/A	N/A	RNA-TK1030	350	N/A
	L	HNO_3	1.5	N	N/A	N/A	RNA-TK1040	400	N/A
	L	HNO_3	1.5	N	N/A	N/A	RNA-TK1041	5	N/A
	L	HNO_3	Variable	N	RNA-TK1421	150 Note 2	N/A	N/A	N/A

Table 8-2a. Chemicals and Chemical Tanks or Containers in the BRP, BAP, and BMP (continued)

Chemical	Form	Symbol, Usage	Concentration		BRP		BAP		BMP
			Quantity[3]	Units	Tank	Capacity (gal, U.N.O.)	Tank	Capacity (gal, U.N.O.)	Capacity
Nitrogen Tetroxide	L	N_2O_4	100	%	Cylinders	1 Ton (240 gal)	N/A	N/A	N/A
	L	N_2O_4	100	%	GNO-TK1300	1 Ton (240 gal)	N/A	N/A	N/A
	L	N_2O_4	100	%	GNO-TK1310	1 Ton (240 gal)	N/A	N/A	N/A
Oxalic Acid	S	$H_2C_2O_4$	100	%	Bags and HOPPER 1120	TBD	N/A	N/A	N/A
	L	$H_2C_2O_4$	0.7	M	ROA-TK1120	416	ROA-TK1130	459	N/A
	L	$H_2C_2O_4$	0.7	M	N/A	N/A	ROA-TK1131	5	N/A
	L	$H_2C_2O_4$-HNO_3	0.05	M	N/A	N/A	ROA-TK1140	162	N/A
	L	$H_2C_2O_4$-HNO_3	0.05	M	N/A	N/A	ROA-TK1141	5	N/A
Plutonium Dioxide (polished)	S	PuO_2	100	%	N/A	N/A	KCC–Pot	2.2 kg	997.5 kg (2.5 kg /pot 399 pots)
	S	PuO_2	100	%	N/A	N/A	KCB-HPR1000	17.6 kg	N/A
	S	PuO_2	100	%	N/A	N/A	KCB-HPR2000	17.6 kg	N/A
Plutonium Dioxide (unpolished)	S	PuO_2	100	%	N/A	N/A	KDA-HPR9000	6 kg	8640 kg (5 kg (max)/ container*1728 containers)
	S	PuO_2	100	%	N/A	N/A	KDA-HPR9100	6 kg	N/A
Plutonium Oxalate	L	$Pu(C_2O_4)_2$	25.1	g(Pu)/liter	N/A	N/A	KCA-PREC5000	5	N/A
	L	$Pu(C_2O_4)_2$	25.1	g(Pu)/liter	N/A	N/A	KCA-PREC6000	5	N/A

Table 8-2a. Chemicals and Chemical Tanks or Containers in the BRP, BAP, and BMP (continued)

Chemical	Form	Symbol, Usage	Concentration		BRP		BAP		BMP
			Quantity[3]	Units	Tank	Capacity (gal. U.N.O.)	Tank	Capacity (gal. U.N.O.)	Capacity
Plutonium Nitrate	L	$Pu(NO_3)_3$ + $Pu(NO_3)_4$	40	g(Pu)/liter	N/A	N/A	KPA-TK1000	1000 liters	N/A
	L	$Pu(NO_3)_4$	39.9	g(Pu)/liter	N/A	N/A	KPA-TK7000	1000 liters	N/A
	L	$Pu(NO_3)_4$	40.9	g(Pu)/liter	N/A	N/A	KDB-TK7000	700 liters	N/A
	L	$Pu(NO_3)_4$	40.9	g(Pu)/liter	N/A	N/A	KDB-TK5000	400 liters	N/A
	L	$Pu(NO_3)_4$	40.9	g(Pu)/liter	N/A	N/A	KDB-TK6000	400 liters	N/A
	L	$PuO_2(NO_3)_2$	229	g(Pu)/liter	N/A	N/A	KDB-EZR1000	52 liters	N/A
	L	$PuO_2(NO_3)_2$	229	g(Pu)/liter	N/A	N/A	KDB-EZR2000	52 liters	N/A
	L	$PuO_2(NO_3)_2$ + $Pu(NO_3)_4$	95.2	g(Pu)/liter	N/A	N/A	KDB-TK3000	150 liters	N/A
	L	$PuO_2(NO_3)_2$ + $Pu(NO_3)_4$	95.2 (R25)	g(Pu)/liter	N/A	N/A	KDB-TK4000	150 liters	N/A
	L	$Pu(NO_3)_4$	39.9 (R25)	g(Pu)/liter	N/A	N/A	KCA-TK1000	600 liters	N/A
	L	$Pu(NO_3)_4$	39.9 (R25)	g(Pu)/liter	N/A	N/A	KCA-TK2000	600 liters	N/A
Silver Nitrate	L	$AgNO_3$	2	N	N/A	N/A	Bottles	TBD	N/A
	L	Ag^+-HNO_3	1	N	N/A	N/A	RSN-TK1210	30	N/A

Table 8-2a. Chemicals and Chemical Tanks or Containers in the BRP, BAP, and BMP (continued)

Chemical	Form	Symbol, Usage	Concentration		BRP		BAP		BMP
			Quantity[3]	Units	Tank	Capacity (gal, U.N.O.)	Tank	Capacity (gal, U.N.O.)	Capacity
Sodium Carbonate	S	Na_2CO_3	100	%	Bags	TBD	N/A	N/A	N/A
	L	Na_2CO_3	0.3	M	RSC-TK1240	46	RSC-TK1250	46	N/A
Sodium Hydroxide	L	NaOH,Soda	10	N	Tote Tank	126	Bottles	TBD	N/A
	L	NaOH,Soda	0.1	N	N/A	N/A	RSH-TK1280	40	N/A
	L	NaOH,Soda	0.1	N	N/A	N/A	RSH-TK1290	40	N/A
Sodium Nitrite	L	$NaNO_2$	400	g/L	N/A	N/A	Tote	TBD	N/A
	L	$NaNO_2$	400	g/L	N/A	N/A	RSI-TL1250	71	N/A
Sodium Sulfite	S	Na_2SO_3	100	%	RSS-FDR1300	TBD	N/A	N/A	N/A
	L	Na_2SO_3	0.5	M	RSS-TK1310	238	RSS-TK1330	297	N/A
Tributyl Phosphate	L	solvent, TBP	100	%	Tote Tank	126	RTP-TK1011	5	N/A
	L	solvent, TBP	100	%	RTP-TK1010	80	RTP-TK1015	40	N/A
	L	TBP+diluent	30	%	N/A	N/A	KPB-TK2000	500 liters	N/A
	L	TBP+diluent	30	%	N/A	N/A	RTP-TK1020	30	N/A
Uranium Dioxide	S	UO_2	100	%	N/A	N/A	N/A	N/A	1 drum 200 kg (max) /drum
	S	UO_2	100	%	N/A	N/A	N/A	N/A	1 drum 200 kg (max) /drum
	S	UO_2	100	%	N/A	N/A	N/A	N/A	2 drums 200 kg (max) /drum

Table 8-2a. Chemicals and Chemical Tanks or Containers in the BRP, BAP, and BMP (continued)

Chemical	Form	Symbol, Usage	Concentration		BRP		BAP		BMP
			Quantity[3]	Units	Tank	Capacity (gal, U.N.O.)	Tank	Capacity (gal, U.N.O.)	Capacity
Uranyl Nitrate	L	$UO_2(NO_3)_2$	0.64	g(U)/liter	N/A	N/A	KDB-TK5000	400 liters	N/A
	L	$UO_2(NO_3)_2$	0.64	g(U)/liter	N/A	N/A	KDB-TK6000	400 liters	N/A
	L	$UO_2(NO_3)_2$	0.64	g(U)/liter	N/A	N/A	KDB-TK7000	700 liters	N/A
Zinc Stearate	S	Dry lubricant	100	%	N/A	N/A	N/A	N/A	TBD
	S	Dry lubricant	100	%	N/A	N/A	N/A	N/A	16-L (hopper)
Zirconium Nitrate	L	$Zr(NO_3)_2 \cdot 5H_2O$	10	g(Zr)/liter	TBD	40	TBD	40	N/A

Table 8-2a Notes:

1. Diluent and nitric acid are recovered in the Aqueous Polishing process. The preparation of these reagents will be drastically reduced, once the AP process is in operation, as recovered reagents will become available.
2. Drain tanks are normally empty.
3. Approximate Values

Table 8-2d. Anticipated Gas Storage Area Inventory

Chemical	Anticipated Gas Storage Area Inventory
Argon	Two (2) 3,000 gallon liquefied gas storage tanks
Argon-Hydrogen	One tube trailer - 56,000 scf
Argon-Methane (P10)	One tube trailer - 45,000 scf
Helium	One large tube trailer – 140,494 scf
Hydrogen	Two (2) tube trailers – 43,000 scf each
Nitrogen	Two (2) buffer tanks – 1209 and 11 cu ft Liquid nitrogen storage tank – 9000 gallons
Oxygen	Two (2) cylinders – 6250 scf each

Table 8-3. Reaction Products of the Aqueous Polishing Process

(Normal Operations)

Chemical	Formula	Comment
Alkaline Wastes (including dibutyl phosphate and monobutyl phosphate)	Various	Alkaline wastes are generated in the Solvent Recovery Unit as a result of washing solvent with sodium carbonate and sodium hydroxide solutions (Note 3)
Carbon Dioxide	CO_2	Reaction product when plutonium oxalate is transformed into PuO_2 in the Oxalic Precipitation and Oxidation Unit (Note 3)
Carbon Monoxide	CO	Reaction product when plutonium oxalate is transformed into PuO_2 in the Oxalic Precipitation and Oxidation Unit (trace quantities only) (Note 3)
Chlorine	Cl_2	Reaction product from dissolution of AFS material in the Dechlorination Dissolution Unit (subsequently treated in the dechlorination scrubbing column) (Note 2).
Hydrogen	H_2	Produced from radiolysis and electrolysis reaction (Note 4)
Nitrogen Oxides	NO_x	Reaction product from dissolution process units and excess reactant from the Purification Cycle oxidation column (Note 2)
Nitrogen	N_2	Reaction product of several reactions in the Purification Cycle oxidation column; reaction product in dechlorination scrubbing column of the Dechlorination Dissolution Unit (Note 3)
Nitric Acid	HNO_3	Reformed in NO_x scrubbing column (UO_2 Dissolution Unit and Offgas Treatment Unit) (Note 1)
Nitrous Acid	HNO_2	Always present in nitric acid solutions (Note 3)

Table 8-3. Reaction Products of the Aqueous Polishing Process (continued) (Normal Operations)

Chemical	Formula	Comment
Nitrous Oxide	N_2O	Reaction product of several reactions in the Purification Cycle oxidation column (Note 2)
Oxygen	O_2	Reaction product of hydrogen peroxide decomposition during PuO_2 dissolution in the Dissolution Unit (Note 3)
Plutonium Dioxide	PuO_2	Reformed in the calcining furnace of the Oxalic Precipitation and Oxidation Unit from the plutonium oxalate feed (Note 1)
Plutonium Oxalate	$Pu(C_2O_4)_2$	Precipitated in the Oxalic Precipitation and Oxidation Unit from the reaction of plutonium nitrate with oxalic acid (Note 1)
Plutonium (III, IV, VI) Nitrate	$Pu(NO_3)_3$, $Pu(NO_3)_4$, $PuO_2(NO_3)_2$	Plutonium (VI) Nitrate - formed from the dissolution of plutonium dioxide in the Dissolution Unit and in the evaporator of the Oxalic Mother Liquor Recovery Unit (Note 1) Plutonium (IV) Nitrate – formed from the addition of hydrogen peroxide to the plutonium (VI) nitrate solution in the Dissolution Unit (Note 1) Plutonium (III) Nitrate – formed from the reduction of plutonium (IV) nitrate solution with HAN in the Purification Unit (Note 1)
Sodium Chloride	NaCl	Reaction product in the dechlorination scrubbing column of the Dechlorination Dissolution Unit (Note 3)
Uranyl Nitrate	$UO_2(NO_3)_2$	Uranyl Nitrate is formed as an intermediate product from the dissolution of plutonium dioxide in the Dissolution Unit.

Table 8-3. Reaction Products of the Aqueous Polishing Process (continued) (Normal Operations)

Chemical	Formula	Comment
Water	H_2O	Reaction product of several reactions in the Purification Cycle oxidation column; reaction product of hydrogen peroxide decomposition during PuO_2 dissolution in the Dissolution Unit (Note 3)

Table 8-3 Notes:

1. Chemical consequence analyses have been performed for nitric acid, uranyl nitrate and the plutonium compounds. Inventories are identified in Table 8-2a.
2. Chemical consequence analyses have been performed for chlorine and nitrogen oxides.
3. Because of low rate of production and/or lack of toxicity, inventories are not quantified for the purposes of calculating chemical consequences to the site worker or the IOC from spills or releases.
4. The generation of hydrogen is considered in the design of the scavenging air system.

Table 8-4. Process Chemical Hazardous Characteristics and Incompatibilities

Form	Chemical	Corrosive	Flammable	Explosive	Chemical Burn	Toxic	Incompatibilities
Liquid	Nitric Acid (13.6N)	x			x	x	Organics, Hydrogen Peroxide, Hydroxylamine Nitrate, Hydrazine Monohydrate, Sodium Carbonate, Sodium Hydroxide
	Hydrogen Peroxide			x	x	x	Organics, Nitric Acid, Manganese (metal), Hydrazine, Sodium Carbonate, Metallic Salts
	Tributyl Phosphate (solvent)		x	x	x	x	Ammonia, Nitric Acid, Oxidizing Agents, Strong Bases
	Diluent (C10-C13 isoalkane)		x	x		x	Oxidizing Agents, Oxygen
	Sodium Carbonate (also present as a solid)					x	Aluminum, Acids, Hydrogen Peroxide
	Demineralized Water						
	Hydroxylamine Nitrate (HAN)	x		x	x	x	Bichromate and Permanganate of Potassium, Copper Sulfate, Zinc, Strong Oxiders, Strong Reducing Agents, Nitric Acid, Combustible Materials
	Hydrazine Monohydrate	x		x	x	x	Oxidizing Agents (Nitric Acid), Metals, Asbestos
	Sodium Hydroxide	x			x	x	Acids, Aluminum and other metals, Organic Halogens (especially Trichlorethylene), Sugars
	Aluminum Nitrate	x			x	x	Combustible Materials, Strong Reducing Agents, Metals, Water
	Hydrazine Nitrate	x			x	x	Acids, Strong Oxidizers, Metal Salts
	Isopropanol		x			x	Oxidizing Agents
	Zirconium Nitrate	x			x	x	Combustible Materials, Strong Reducing Agents, Metals
Gas	Dinitrogen Tetroxide/Nitrogen Dioxide	x		x	x	x	Reducing Agents, Organics, Metals
	Helium						
	Argon						
	Hydrogen		x	x			
	Oxygen					x	Organics
Solid	Silver Nitrate (also present as liquid)	x		x	x	x	Ammonia, Carbonates, Chlorides
	Manganese Nitrate (also present as liquid)	x		x	x	x	Strong Reducing Agents, Combustible Materials
	Oxalic Acid (also present as liquid)				x	x	Silver, Sodium Chloride, Sodium Hypochlorite
	Azodicarbonamide						Strong Oxidizing Agents
	Zinc Stearate		x			x	Strong Oxidizing Agents, Acids

Table 8-5. TEELs Used as Chemical Limits for Chemicals at the MFFF (Note 1) (mg/m^3)

Name	TEEL-1	TEEL-2	TEEL-3
Aluminum Nitrate	15	15	500
Azodicarbonamide	125	500	500
Chromic (III) Acid	1	2.5	25
Chlorine*	3	7.5	60
Diluent (C10-C13 Isoalkanes) (Note 2)	5	35	200
Decane (C10)	5	35	25000
Undecane (C11)	6	40	200
Dodecane (C12)	15	100	750
Tridecane (C13)	60	400	500
Ferrous sulfate	7.5	12.5	350
Fluorine*	0.75	7.5	30
Hydrazine Monohydrate	0.0075	0.06	50
Hydrazine Nitrate	3	5	5
Hydrofluoric Acid*	1.5	15	40
Hydrochloric Acid*	4	30	200
Hydrogen Peroxide*	12.5	60	125
Hydroxylamine Nitrate	15	26	125
Iron	30	50	500
Isopropanol	1000	1000	5000
Manganese Nitrate	10	15	500
Manganous Sulfate	7.5	12.5	500
Nitric Acid*	2.5	15	200
Nitric Oxide	30	30	125
Nitrogen Dioxide	7.5	7.5	35
Dinitrogen Tetroxide	15	15	75
Oxalic Acid	2	5	500
Potassium Permanganate	7.5	15	125
Silver Nitrate	0.03	0.05	10
Silver Oxide	30	50	75
Sodium	0.5	5	50
Sodium Carbonate	30	50	500
Sodium Hydroxide*	0.5	5	50
Sodium Nitrite	0.125	1	60

Table 8-5. TEELs Used as Chemical Limits for Chemicals at the MFFF (Note 1) (continued)

(mg/m^3)

Name	TEEL-1	TEEL-2	TEEL-3
Sodium Sulfite	30	50	100
Sulfuric Acid*	2	10	30
Sulfamic Acid	40	250	500
Thenoyl TrifluoroAcetone	3.5	25	125
Tributyl Phosphate	6	10	300
Uranium Dioxide	0.6	1	10
Uranyl Nitrate	1	1	10
Xylene	600	750	4000
Zinc Stearate	30	50	400
Zirconium nitrate	35	35	50

* Values are based on Emergency Response Planning Guideline (ERPG) concentrations

Table 8-5 Notes:

1. Temporary Emergency Exposure Limits (TEELs), Revision 18, are derived from approved methodologies developed by Department of Energy Subcommittee on Consequence Assessment & Protective Actions (SCAPA) and are identified in WSMS-SAE-02-0001.
2. The TEEL values for diluent represent the most conservative value in each category among the following primary constituents: n-decane, n-undecane, n-dodecane, and n-tridecane.

Table 8-5a. Chemical Limits Used for Control Room Consequence Calculations at the MFFF (mg/m^3)

Name	Concentration Limit (mg/m^3)	Source of Limit
Aluminum Nitrate	15	TEEL-2
Azodicarbonamide	500	TEEL-2
Chromic (III) Acid	25 mg Cr (III)/m^3	IDLH
Chlorine	29	IDLH
Diluent (C10-C13 Isoalkanes)	35	TEEL-2
Ferrous sulfate	12.5	TEEL-2
Fluorine	30	TEEL-3
Hydrazine Monohydrate	0.06	TEEL-2
Hydrazine Nitrate	5	TEEL-2
Hydrofluoric Acid	25	IDLH
Hydrochloric Acid	75	IDLH
Hydrogen Peroxide	106	IDLH
Hydroxylamine Nitrate	26	TEEL-2
Iron	500	TEEL-3
Isopropanol	5000	IDLH
Manganese Nitrate	500 mg Mn/m^3	IDLH
Manganous Sulfate	500 mg Mn/m^3	IDLH
Nitric Acid	66	IDLH
Nitric Oxide	125	IDLH
Nitrogen Dioxide	35	TEEL-3
Nitrogen Tetroxide	15	TEEL-2
Oxalic Acid	500 mg/m^3	IDLH
Potassium Permanganate	15	TEEL-2
Silver Nitrate	10 mg Ag/m^3	IDLH
Silver Oxide	10 mg Ag/m^3	IDLH
Sodium	5	TEEL-2
Sodium Carbonate	50	TEEL-2
Sodium Hydroxide	10 mg/m^3	IDLH
Sodium Nitrite	1	TEEL-2

Table 8-5a. Chemical Limits Used for Control Room Consequence Calculations at the MFFF (mg/m^3) (continued)

Name	Concentration Limit (mg/m^3)	Source of Limit
Sodium Sulfite	50	TEEL-2
Sulfuric Acid	15 mg/m^3	IDLH
Sulfamic Acid	250	TEEL-2
Thenoyl TrifluoroAcetone	25	TEEL-2
Tributyl Phosphate	300	TEEL-3
Uranium Dioxide	10 mg U/m^3	IDLH
Uranyl Nitrate	10 mg U/m^3	IDLH
Xylene	3900	IDLH
Zinc Stearate	50	TEEL-2
Zirconium nitrate	10 mg Zr/m^3	IDLH

Table 8-6. Application of Chemical Limits to Qualitative Chemical Consequence Categories

Consequence Category	Worker	IOC
High	Concentration ≥ TEEL-3	Concentration ≥ TEEL-2
Intermediate	TEEL-3 > Concentration ≥ TEEL-2	TEEL-2 > Concentration ≥ TEEL-1
Low	TEEL-2 > Concentration	TEEL-1 > Concentration

9. RADIATION SAFETY

This chapter addresses the radiological health and safety of workers during normal operations and anticipated events. The requirements for radiation safety are found in 10 CFR Part 20, *Standards for Protection Against Radiation*, and 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*. This chapter focuses primarily on occupational exposure during normal and anticipated abnormal events. Public and environmental protection is discussed in Chapter 10, and design basis accidents are discussed in Chapter 5.

The potential for occupational exposure at the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) exists primarily as a result of the processing of plutonium (i.e., potential internal exposure from inhalation) and also as a result of handling other radioisotopes (i.e., direct external exposure). The primary design features that limit exposure in accordance with ALARA (as low as reasonably achievable) goals are confinement systems (e.g., gloveboxes, process cells, ventilation), monitoring, alarms, and radiation shielding. Confinement systems are described in detail in Section 11.4.

The design of the facility ensures that the total effective dose equivalent (TEDE) to individual members of the public from the MFFF will not exceed 100 mrem in a year from normal operations and anticipated operational occurrences. The design also ensures that annual occupational doses are maintained below a TEDE of 5 rem and 50 rem to any extremity.

The TEDE design goal for individual workers will be ALARA and less than 500 mrem/yr to most of the operating team members, with an extremity exposure goal of less than 10 rem/yr.

The annual occupational exposure limits from 10 CFR Part 20 are as follows:

• Total (CEDE + DDE) = TEDE	5 rem (0.05 Sv)
• Lens of Eye (LDE)	15 rem (0.15 Sv)
• Other Organs (CDE + DDE)	50 rem (0.5 Sv)
• Skin or Extremity (SDE)	50 rem (0.5 Sv)

Note: CEDE is committed effective dose equivalent; DDE is deep dose equivalent; LDE is lens of the eye dose equivalent; CDE is committed dose equivalent; and SDE is shallow dose equivalent. The extremities are considered to be the hand, elbow, arm below the elbow, foot, knee, and leg below the knee.

Potential occupational radiation exposure from exposure to external radiation sources is evaluated and minimized throughout the facility design process using three techniques: (1) general radiation zoning criteria, (2) the ABAQUES Method, and (3) design ALARA evaluations. The application of these criteria is sequential. The general radiation zoning criteria are established at the outset of the facility design. The ABAQUES Method is performed during the facility design, and the design ALARA evaluation is performed after the preliminary design. The design will be reviewed for ALARA concerns in accordance with 10 CFR Part 20 to ensure that exposures to workers are within the limits specified therein.

This chapter describes the design features of the MFFF and programmatic elements that together minimize occupational exposure.

9.1 RADIATION SAFETY DESIGN FEATURES

The MFFF design objectives ensure that operation of the MFFF is in accordance with 10 CFR Part 20 and the ALARA policy. Engineering features and controls are implemented during the facility design and operations to ensure that occupational doses are ALARA. The MFFF design objectives include, as a minimum, the following criteria:

- Integrating ALARA features based on experience from operating facilities into facility design and operating procedures with technological, economic, and social factors taken into consideration
- Maintaining radiation zoning criteria and design goals through access restrictions and shielding
- Estimating individual and collective doses to ensure the design provides for exposures to be ALARA
- Conducting periodic training and exercises for management, engineers, and designers in radiation protection principles and procedures, individual and group protective measures, specific facility procedures, and emergency response
- Integrating appropriate radiation protection controls into work activities.

9.1.1 ALARA Design Considerations

The purpose of this section is to summarize the elements showing that the design for construction and operation of the facility is adequate to protect the radiological health and safety of MFFF workers. Environmental Protection is discussed in Chapter 10.

The MFFF design reflects consideration of ALARA principles. Specific ALARA considerations in the MFFF design include the following:

- Control of plutonium particulate to prevent inhalation by confining radioactive materials in process equipment and in gloveboxes
- Multiple-zone ventilation system design
- Continuous remote monitoring of airborne conditions in the access areas
- Use of automated and remotely operated equipment to minimize personnel exposure
- Removal of radioactive sources before most maintenance operations
- Placement of radiation shields between radioactive sources and the operators according to the intensity, nature, and penetrating power of the radiation
- Design of structures, systems, and components (SSCs) that require a minimum of maintenance or repair to minimize personnel stay times in radiation areas

end of the AP process. This will have little impact on facility occupational doses since the operations in these cells are performed remotely.

Polished plutonium contains much less of the daughter products (or impurities from feed material originating from sources other than the PDCF), such that the radiation levels are lower. The master blend is a maximum of 20% PuO_2 with the balance being depleted UO_2. The final blend will be in the range of 2% to 6%. The conservative estimate for the long-term average for personnel exposure is assumed to be 5% PuO_2 + 95% depleted UO_2. Table 9-3 shows the non-polished plutonium source at 0 year decay, 40 year decay, and 70 year decay. Table 9-4 shows polished plutonium from AP, master blend, and final blend sources. Table 9-5 shows the AP raffinate sources.

The Radiological Isotopic Composition (RIC) is back-calculated using the decay schemes for the affected isotopes from Today's Isotopic Composition (TIC), which is based on 40 years of decay since the plutonium was first refined. The Final Isotopic Composition (FIC) is the decay of the TIC to a total of 70 years since the plutonium was first refined. The Raffinates Isotopic Composition (RAIC) corresponds to all of the mass of ^{241}Am obtained at the entrance of the AP Area; all of the daughters (except neptunium and thorium) produced by the decay of plutonium during 70 years; and a small amount of plutonium and uranium corresponding to the repartition of plutonium and uranium in the AP process. These notations are used in Tables 9-3 and 9-5.

Multiple sources are identified to maximize photon and neutron source terms. The 0-year decay sources represent the initial isotopic composition of the product material. The 40-year decay sources represent the expected isotopic compositions at the start of facility operations. The 70-year decay sources are the isotopic compositions at the maximum decay time expected at the facility. Non-routine and accident sources will be addressed in the license application for possession and use of SNM, as will additional details concerning shielding analyses (i.e., model and geometries).

A residual source of contamination is conservatively estimated for loss-of-confinement analysis and extremity dose analysis based on MELOX operating experience.

The occupational dose is assessed during the design phase. Significant occupational doses are evaluated for design enhancements to reduce the potential doses. ALARA evaluations are documented and summarized in the license application.

9.1.3.2 Source Pertinent Information

The sources identified in Section 9.1.3.1 are used to:

- Evaluate consequences in the safety assessment of the design basis
- Provide input to shielding codes used in the design
- Establish design features
- Develop plans and procedures
- Assess occupational dose.

9.1.3.3 MELOX and MFFF Source Term Comparison

The source term comparison in Table 9-6 is made to assist in extrapolating existing MELOX radiation exposure data to that for the MP Area. No source comparison is used for the AP process since the expected occupational exposure is small. In the absence of radiation dose rate and activity data at this time, existing MELOX data are extrapolated for the MFFF to estimate the expected occupational dose. These data provide a focus for design evaluations.

The specific activities associated with these sources are used in shielding calculations to determine the ratio of the dose rates for MELOX and the MFFF. In this way, the sources can be compared to extrapolate expected dose rates in the MFFF. Tables 9-7 and 9-8, along with Figures 9-10 and 9-11, provide comparisons of photon and neutron spectra, respectively.

The ratio of the MELOX photon dose to the MFFF photon dose is 20:1. This ratio is based on a calculated dose comparison for a specific geometry of the MELOX fuel (8.5%) to the final blend MFFF fuel (5%).

The ratio of the MELOX neutron dose to the MFFF neutron dose is 11:1. This ratio is based on the ratio of the intensities and on a comparison of the calculated dose rates for specific geometries from each facility.

9.1.4 Ventilation Systems and Glovebox Design

The design and operation of the ventilation system and gloveboxes are to protect workers from airborne radioactive material such that the limits of 10 CFR Part 20 are not exceeded during routine and non-routine operations and anticipated events.

The design objectives for the ventilation systems and gloveboxes ensure that during routine and non-routine operations and anticipated events, the airborne concentration in occupied operating areas will remain well below the limits of 10 CFR Part 20, Appendix B. Engineering controls are preferred over the use of respirators.

Uninterruptible power supplies (UPSs) ensure air monitoring and warning systems associated with the ventilation system and gloveboxes will function during a loss of power unless they can tolerate a temporary loss of function without loss of data. The air monitoring and warning systems are designed with a standby power supply.

Chapter 11 provides details of the system design for the ventilation system and gloveboxes.

9.1.4.1 Ventilation System Design

The ventilation system is designed to incorporate features that ensure workers are protected, to the greatest extent practical, from airborne radioactive material during normal and accident conditions. Many of the ventilation system design features described in this section also promote reduced airborne effluent releases and minimize exposures.

10. ENVIRONMENTAL PROTECTION

The components of the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) Environmental Protection Program include the following:

- The Radiation Safety Program, which is established to control and assess the level of radioactive releases to the environment during normal and anticipated off-normal operations, minimize facility contamination, and minimize waste generation
- The Effluent Monitoring Program, which is established to measure and monitor the radioactive effluents released from the facility
- The Environmental Monitoring Program, which is established to monitor potential environmental impacts from operations.

10.1 RADIATION SAFETY PROGRAM

The Radiation Safety Program is described in Chapter 9. That portion of the Radiation Safety Program related to protection of the environment is given herein.

10.1.1 ALARA Goals for Effluent Control

Effluent control begins with the facility design by limiting the material capable of becoming a radioactive effluent. The MFFF processes generate minimal airborne radioactive effluents, and no radioactive liquid effluents are released directly to the environment.

The as-low-as-reasonably-achievable (ALARA) goal for airborne radioactive effluents released from the MFFF is 20% of the effluent concentrations from 10 CFR Part 20, Appendix B, Table 2, Column 1. Additionally, the goal for total effective dose equivalent to the individual member of the public likely to receive the highest dose from the facility, based on estimates for normal operations, is less than 10 mrem/yr. Normal operating release values are calculated at the restricted area boundary (RAB). The dispersion model calculates the X/Q for the 50 % annual average for a receptor at the closest point to the stack (170.6 ft [52 m]). The X/Q value is 2.5E-4 sec/m^3. The maximum dose contribution is from Pu-239 and the concentration is 7.25E-16 microCi/ml, which is less than the ALARA goal and the constraint on air emissions of 10 CFR §20.1101(d). Procedures will be established to report exceedances of the constraint level in accordance with 10 CFR §20.2203 and to take prompt corrective action to prevent recurrence.

An ALARA goal for radioactive liquid effluents is not provided since the facility design precludes the release of radioactive liquid effluents to the environment.

10.1.2 Effluent Controls to Maintain Public Doses ALARA

As previously indicated, the MFFF does not discharge any radioactive liquid directly to the environment. The only nonradioactive liquid effluent is from storm drains. The sanitary drains are not in radiation areas.

Radioactive airborne effluents from the MOX processing (MP) and aqueous polishing (AP) process areas are filtered and released through the stack located on the roof of the MOX Fuel

Fabrication Building. Design features that support reduced airborne effluent releases to maintain public doses ALARA include the placement and use of filter banks containing a minimum of two stages of high-efficiency particulate air (HEPA) filters. These filters minimize environmental releases by removing particulates present in ventilation exhaust. Spaces with the greatest potential for generating airborne contaminants in the effluent (i.e., gloveboxes) are exhausted through these filters prior to discharge to the environment. Design features of the AP ventilation system also take into account potentially corrosive materials.

Specific decontamination factors have not been established for all filters but are expected to be more than adequate to reduce the total radioactivity to acceptable levels. The experience at the MELOX and La Hague facilities is that the concentrations of airborne effluents are less than the minimum detectability of continuous air monitors (CAMs) and samples evaluated in the laboratory.

The combined MP and AP airborne effluents are monitored with two monitoring systems, including two CAMs and two fixed air samplers, with each unit provided air representative of that present in the stack. A representative sample of the particulate effluent from the stack is collected continuously for determination of quantities and average concentrations of radionuclides released. The sampling is conducted regardless of the concentration of radioactive material in the effluent, which is expected to be negligible under normal operating conditions.

Trending of results from effluent monitors, samplers, and other MFFF airborne monitoring equipment provides early indications of elevated radiation environments. Procedures will be developed to identify evaluations and actions to be taken when the concentrations of airborne radioactivity exceed prescribed limits.

To investigate elevated stack releases and/or anomalies, sample connections are installed at key locations in the MP and AP process area ventilation ducts. The placement and use of sample connections are based on the risk to workers and members of the public. The potential for leakage from process systems, equipment, and confinements is also considered. The evaluation focuses on the equipment and spaces with the higher potential for leakage or airborne contaminants (e.g., AP process cells, and AP and MP gloveboxes) as determined by experience at the MELOX and La Hague facilities. During MFFF operations, elevated readings from CAMs and/or fixed air samplers will be used to identify the need to perform maintenance or to take other action to reduce effluent releases. Following a loss of offsite power, the CAMs and fixed air samplers obtain power from the uninterruptible power supply (UPS) and emergency diesel power sources.

10.1.3 ALARA Reviews

ALARA reviews and reports to management include the development of trending charts so that analytical results and effluent monitor readings can be trended against the goals. Abnormal increases in the trending of either the monitor readings or the analytical results are reported to MFFF management as soon as practical. To ensure that releases are maintained ALARA, management is informed of the trends measured against the goals on a quarterly basis. Annually, the goals are reevaluated and new goals are established for the upcoming year.

10.1.4 Waste Minimization and Waste Management

The Waste Minimization Program begins with the process design and continues into operations. During the process design, recycling and reuse are implemented for waste minimization purposes. For operations, waste minimization procedures will provide for separation and segregation of solid and liquid wastes and the removal of packing and shipping materials prior to entry into contaminated areas. Worker training will also be developed.

Many of the design features addressed in the MP and AP process descriptions (Sections 11.2 and 11.3, respectively) perform contamination control and associated waste minimization functions. In addition to the confinement system, the process design reduces the distribution and retention of radioactive materials throughout plant systems by using vacuum systems in the gloveboxes. Airborne dust is collected in dust pots in dedusting systems installed in selected gloveboxes, and the material is recycled. These design features control contamination to ensure that secondary waste production is minimized during plant operation and to ensure that only a minimal amount of contamination is generated. The design incorporates extensive recycling for the materials exiting the main process (e.g., secondary waste streams of the AP process and scraps not meeting specifications in the MP process). The recycling process is designed to minimize the quantity of plutonium in the final waste by using systems that return the radioactive materials to previous steps of the main process.

The following features of the AP process are specifically designed to minimize waste by maximizing recycling or recovery:

- **Acid recovery** – Nitric acid is recovered from the bottom of the rectification column and reused as reagent feedstock in the aqueous polishing units. The distillates from the rectification column are also collected and redistributed to the aqueous polishing process.
- **Solvent regeneration** – Following purification of the plutonium solution in pulsed columns by solvent extraction, the extracted raffinate stream is washed with diluent and routed to the Acid Recovery Unit. The regenerated solvent is adjusted with the addition of pure tributyl phosphate and reused in the Purification Cycle.

The design includes systems that provide separation and segregation of streams to minimize the amounts and types of contaminated materials. There are separate collection tanks for laboratory rinse waters and sanitary washings. There are also features to concentrate streams through evaporation. The acid recovery evaporator produces distillates that are relatively free of radioactivity and can be reintroduced into the process, while its concentrates contain wastes that are prepared for disposal.

MFFF waste management is guided by the principles of ALARA, waste minimization, and pollution prevention. Liquid and solid wastes produced in the MFFF will be transferred to the Savannah River Site (SRS) for processing and disposal. DCS has worked closely with SRS during the MFFF design phase and has provided SRS with waste characterization information. SRS has reviewed and evaluated the information in the context of the existing Waste Acceptance Criteria (WACs). DCS is committed to meeting the SRS WAC or providing a stream that qualifies for a WAC Deviation and Exemption.

The WAC for the SRS Waste Solidification Building (WSB) has not been prepared, but the interface between DCS and SRS will ensure that the WSB is designed to manage the MFFF liquid and solid wastes.

The expected and maximum waste volumes and concentrations of the main chemicals and radioisotopes have been computed for the liquid waste streams. The tanks, pumps and transfer lines have been designed on this basis as well as the planned waste transfer frequencies.

The various streams from the MP process are extensively treated to recover feedstock and plutonium to the maximum extent practical, resulting in a very small amount of generated waste that is transferred to SRS. The various waste streams and their disposition are discussed in the following sections.

10.1.4.1 Liquid Waste Management

The quantity of radioactive liquid waste is small because the AP process uses recycling to the extent feasible; all liquid wastes are transferred to SRS. Figure 10-1 depicts the streams from the AP process.

10.1.4.1.1 High-Alpha-Activity and Stripped Uranium Streams

Two liquid streams from the AP process are classified as high-alpha-activity streams: the americium stream and the alkaline wash stream. The excess acid stream, from acid recovery, is also managed as a high-alpha-activity stream because of the stream properties. These three streams are combined and the merged stream is managed as the high-alpha-activity stream. The stripped uranium stream contains less than 1% uranium 235 following isotopic dilution. The stream is managed at the SRS WSB.

The high-alpha-activity and stripped uranium streams are separately pumped to the SRS WSB in dedicated double-walled stainless steel pipes provided with leak detection. The leak detection system provides early warning of any leaks in lines used for transfer of radioactive liquid streams from the MFFF to the WSB so that remedial action may be initiated. The high alpha and stripped uranium liquid transfer lines are designed to withstand the effects of the design basis earthquake and other applicable events as described in Chapter 5.

The waste transfer lines are buried underground and are unlikely to be impacted by load handling activities. The waste transfer lines will be designed to accommodate external loads, including dead loads (soil pressure) and live loads (wheel loads).

Liquid Americium Stream

The raffinate from the Polishing Process contains americium, gallium and traces of plutonium extracted from the plutonium oxide feed and silver from the dissolution unit. This stream is termed the liquid americium stream and is a high-alpha-activity stream. The americium stream, along with the alkaline and excess acid streams, are transferred to the batch constitution tank where they are mixed, analyzed for pH, and then transferred to a high alpha storage tank. The high alpha storage tank along with the high alpha buffer storage tank are a holding point for the high alpha streams and provide 90 days of storage. The contents of the high alpha buffer storage tank are sampled and analyzed to ensure compliance with the SRS WAC before being pumped to the WSB through dedicated double-walled stainless steel pipes provided with leak detection.

Excess Acid Stream

The acid recovery process produces a condensate stream and excess acid. The acid recovery condensate stream is transferred for AP recycled water solution feeding. The excess recycled water is collected in a buffer storage tank, analyzed for activity and transferred to the liquid waste reception unit. The recovered excess acid is expected to be a liquid high-alpha-activity stream and is managed with the high-alpha- activity stream. The excess recovered acid is transferred to a buffer tank and then to the batch constitution tank, where it is mixed with the other high alpha liquid streams and managed as described previously.

Alkaline Wash Stream

The alkaline treatment process generates an alkaline wash stream. After these washings, the alkaline wash stream is transferred to the alkaline waste tank. The alkaline wash stream is then transferred to the batch constitution tank where it is mixed with other high alpha liquid streams and managed as described previously.

Waste Solvent Stream

The alkaline treatment process generates a small quantity of slightly contaminated excess solvent. The slightly contaminated excess solvent is a low-level waste (LLW). Waste solvent is pumped from the solvent recovery tank to an intermediate holding tank where it is sampled to assure compliance with the SRS WAC. The intermediate tank is fitted with mixing and sampling capabilities. The batch is transferred through a dedicated pipe to a 300-gallon carboy or other suitable container located in an enclosure outside the Reagents Process Building.

The carboy transfer operations from MFFF to SRS will be controlled under the radiation protection program as described in Chapter 9. The waste container will be transferred to an SRS vehicle for transport from MFFF. SRS will take possession of the waste prior to reaching the Restricted Area Boundary (RAB) and is responsible for the safe movement and disposition of the waste.

Stripped Uranium Stream

After the uranium-stripping process, the highly enriched uranium undergoes isotopic dilution and is collected in the stripped uranium reception tank. The uranium stream also contains a small amount of plutonium. The uranium stream is sampled and analyzed to ensure that it complies with the WAC. The stripped uranium stream is transferred to the stripped uranium buffer tank for neutralization and acidification before transfer to the stripped uranium transfer tank. The stripped uranium transfer tank is the final holding and sample point for the stripped uranium stream. After verification that the stream complies with the SRS WAC, the stream is transferred to the SRS WSB through dedicated double walled construction piping provided with leak detection.

10.1.4.1.2 Chloride Stream

A dechlorination step is necessary for product quality before dissolution for chlorinated feeds (e.g., AFS). The extracted chlorine is filtered and washed in a scrubbing column. The chlorinated liquid stream is transferred from the dechlorination/dissolution unit to a reception tank in the Waste Reception area. The chloride stream is diluted using chloride free streams destined for SRS LLW treatment. This dilution step will reduce the chloride concentration to a value acceptable to SRS without increasing the total volume of waste being generated. The combined stream will be sampled and analyzed to verify compatibility with SRS site requirements and will then be pumped to the SRS waste treatment facility.

10.1.4.1.3 Potentially Contaminated Water

Potentially contaminated wastewater is collected in the MFFF. This wastewater consists of laboratory rinse water, mop water from washing, MFFF building floor drains, and condensate from room air conditioners. These waters are collected, sampled, and analyzed. After analysis, the water is transferred to the SRS liquid LLW treatment facilities.

Potentially contaminated liquid containment features include the following engineered systems:

- Tanks containing contaminated liquids are located in containment basins.
- Stainless steel-lined floors and portions of walls creating containment basins are used in tank rooms of the AP building.
- Double-wall pipe on transfer lines to SRS.

10.1.4.1.4 Nonhazardous Liquid Waste

Nonhazardous liquid waste includes rinse water and the sanitary waste from sinks, showers, urinals, and water closets. Nonhazardous wastewater, exclusive of the potentially radioactive LLW rinse water, will be discharged to the SRS sanitary sewer system.

10.1.4.2 Solid Waste Management

Solid waste is classified as solid transuranic (TRU) waste, solid mixed TRU waste, solid LLW, solid mixed LLW, hazardous solid waste, and nonhazardous solid waste. Wastes are processed through the waste storage unit prior to transfer to SRS. Solid wastes (with the exception of nonhazardous solid wastes) are transferred to SRS. These solid waste types are discussed in the following sections.

10.1.4.2.1 Solid Transuranic Waste

Solid TRU waste generation is related to the normal process operations, maintenance operations, and replacement of equipment.

Several types of waste originate from glovebox operations. These include cleaning materials, such as cotton, wool, and cellulose fabrics used for cleaning inside the gloveboxes; maintenance wastes, including parts and equipment removed from service; and removed gloves.

Convenience cans are a waste stream originating in the decanning glovebox. Molybdenum boats are a source of waste from the sintering of pellets. Zirconium clads and laboratory wastes (glass) are mainly generated by control operations on samples at each production batch. Balls from the ball mills and welding samples are other metallic wastes.

HEPA filters used in the gloveboxes are another source of waste. Decloggable filters will be used in the grinding gloveboxes, thus reducing the number of HEPA filters disposed and providing an opportunity to recover plutonium.

Plastic wastes include latex, neoprene, and polyurethane gloves, as well as polyvinyl chloride, polyethylene, or polyurethane. Other wastes include grinding wheels and ceramic wastes from maintenance and repair of the sintering furnaces, staff clothing, and other maintenance-related wastes.

Solid TRU waste streams are separated at the source of generation and packaged in standard waste containers. Waste drums are marked at the point of generation, uniquely labeled, and tracked through storage and shipping.

10.1.4.2.2 Solid Mixed Transuranic Waste

Mixed TRU waste contains both a hazardous component and a TRU radioactive component. Solid mixed TRU waste produced at the MFFF may include lead-lined gloves, if they are used in the gloveboxes. The gloves, if they are used, are considered mixed TRU waste because they meet the criterion for TRU waste and the criterion for the toxicity characteristic for lead. Mixed TRU waste is handled as discussed above for solid TRU waste.

10.1.4.2.3 Solid Low-Level Waste

LLW will be generated as a result of normal MFFF process operations and maintenance activities and includes alpha-emitting TRU radionuclides with half-lives greater than 20 years but in concentrations less than 100 nCi/g of the waste matrix without regard to source or form. LLW is expected from normal process operations and from routine and nonroutine maintenance activities. Solid LLW will include the following material: cleaning materials (e.g., cotton, wool, and cellulose fabrics used for cleaning gloveboxes), parts and equipment, plastic wastes, inner cans, room filters, uranium area waste, wipes, packaging foils, protective clothing, and maintenance-related wastes.

All waste that is potentially contaminated with plutonium is treated in the same fashion, with steel drums used as the standard waste containers. However, the waste category is not determined until the waste containers are counted and categorized by waste type. They are then separated and stored as TRU waste, mixed TRU waste, LLW, and mixed LLW.

10.1.4.2.4 Solid Mixed Low-Level Waste

Mixed LLW is LLW determined to contain both a hazardous component subject to the Resource Conservation and Recovery Act (RCRA) and source, special nuclear, or byproduct material. Mixed LLW includes hazardous materials contaminated with plutonium and scintillation vials from the analytical laboratory.

Mixed LLW is packaged and transferred to SRS in a manner consistent with the SRS requirements. To the extent practical, commingling of waste from streams requiring different treatment technologies will be prevented.

Containers of hazardous waste known or suspected to be contaminated with radioactive material are uniquely labeled and tracked through storage and shipping. The mixed LLW is then transferred to SRS.

10.1.4.2.5 Hazardous Solid Waste

Hazardous solid waste is waste that is, or contains, a listed hazardous waste or that exhibits one of the four U.S. Environmental Protection Agency (EPA) hazardous waste characteristics (i.e., ignitability, corrosivity, reactivity, and toxicity). Hazardous waste includes some wastes from the analytical laboratory that are not contaminated with radioactive material. MFFF hazardous waste is transferred to SRS.

10.1.4.2.6 Nonhazardous Solid Waste

Nonhazardous waste is waste that is not or does not contain listed hazardous waste, that does not exhibit one of the four EPA hazardous waste characteristics, and that does not contain radioactive material. Nonhazardous solid waste includes office trash and other industrial wastes from utility and maintenance operations. Nonhazardous solid waste is packaged in conformance with standard industrial practice. Recyclable solid wastes (e.g., office paper, metal cans, and plastic and glass bottles) are sent offsite for recycling. The remaining solid sanitary waste is sent to a solid waste landfill.

10.1.4.3 Laboratory Waste

The laboratory is treated separately because it is a discrete source of waste and may produce various types of radioactive and hazardous wastes. The laboratory receives samples from the MP process as powder and pellets and as vials of liquid intermediates from the AP process. Laboratory waste solutions containing plutonium are collected and recycled back to the AP process according to solution composition.

Chemical reagents contaminated with radioactivity may be packaged in the laboratory and disposed of as solid mixed LLW. Hazardous chemical waste is collected and packaged for transfer to SRS.

10.2 EFFLUENT MONITORING PROGRAM

10.2.1 Airborne Effluent Monitoring and Sampling

Airborne emissions from the MFFF are controlled by the building and glovebox ventilation systems, the process ventilation offgas system, and MFFF stack HEPA filters.

10.2.1.1 HEPA Filter Testing

HEPA final filter banks contain provisions for dioctyl phthalate (DOP) testing. Following maintenance on the final filter banks, such HEPA filters are DOP-tested prior to being placed in service.

10.2.1.2 Radionuclides in Airborne Effluents

Estimated annual airborne effluent releases from the MFFF stack are based on experience at the MELOX and La Hague facilities. Extensive experience at these facilities has shown that the concentrations of airborne effluents are less than the minimum detectability of CAMs and samples evaluated in the laboratory. Due to the content of incoming feedstock and MFFF processes, radioactive airborne releases contain isotopes of plutonium, uranium, americium, and other minor dose contributors. The maximum concentrations of radioactive airborne effluents, averaged over a calendar year, are expected to be much less than the values in 10 CFR Part 20, Appendix B, Table 2. These airborne effluent values are approximately 9 wt % uranium and 4 wt % plutonium. Almost all of the uranium generated by MP process area activities is expected to be ^{238}U.

10.2.1.3 Physical and Chemical Characteristics of Radionuclides

Duke Cogema Stone & Webster (DCS) will demonstrate compliance with the annual dose limit in 10 CFR §20.1301 as provided for in 10 CFR §20.1302(b). Therefore, DCS does not need to take into account the actual physical and chemical characteristics of the effluents (e.g., aerosol size distribution, solubility, density, radioactive decay equilibrium, and chemical form).

10.2.1.4 Discharge Locations and Monitoring

The MFFF stack represents the only facility location that has the potential for discharging airborne radionuclides. The various process exhausts are mixed and filtered through at least two HEPA filter stages before being released through the MFFF stack.

Two redundant CAMs and two fixed airborne particulate samplers monitor the MFFF stack. Output from the CAMs alerts personnel in the Polishing Utilities Control Room (located in the Shipping and Receiving Building) and the Respirator Maintenance/Health Physics Office (located in the Technical Support Building), by way of audible and visual alarms, if the airborne radioactive effluent exceeds a prescribed limit.

Continuous sampling of the main stack effluent addresses the combined source of radioactive airborne contaminants from the MP and AP processes during normal and anticipated off-normal operations. To quantify the contribution from each source, two additional CAMs are included to sample the discharged air from the MP and AP process areas. Effluents from areas not used for processing special nuclear material (e.g., laboratories, storage areas, and fuel element assembly areas) are also sampled continuously.

Upstream or local area CAMs are also installed to identify elevated releases resulting from off-normal operations. Data collected from these monitors will support control room operators in locating the source of increases in airborne radioactivity. CAMs are installed to obtain the lowest minimum detectable concentration for monitoring airborne effluents.

Information concerning the following elements associated with airborne effluents will be submitted with the license application for possession and use of special nuclear material:

- A description of the sampling, collection, and analysis procedures, including the minimum detectable concentration of radionuclides, equipment, calibration information, and laboratory quality control procedures
- A description of the proposed action levels and actions to be taken when action levels are exceeded
- The identification of the pathway analysis methods to estimate public doses, including a demonstration of compliance with 10 CFR §20.1301, through a calculation of the total effective dose equivalent to the maximally exposed offsite individual
- A description of the recording and reporting procedures, including event notification for airborne releases.

10.2.2 Liquid Effluent Monitoring

Since there are no radioactive liquid effluents, liquid effluent monitoring is not necessary.

10.3 ENVIRONMENTAL MONITORING PROGRAM

The Environmental Monitoring Program assesses the environmental impact of licensed activities and will include preoperational and operational environmental monitoring.

The objectives of the Preoperational Environmental Monitoring Program are as follows:

- Establish a baseline of existing radiological and biological conditions in the area of the MFFF site
- Determine the presence of any contaminants that could be a safety concern for personnel
- Evaluate procedures, equipment, and techniques used in the collection and analysis of environmental data, and train personnel in their use.

The objective of the Operational Environmental Monitoring Program is to determine whether or not there are adverse impacts from operations that result in radiological and biological effects to the MFFF site and environs.

Radiological impacts to the environment from operation of the MFFF are expected to be minimal. Since the MFFF does not discharge any radioactive liquid directly to the environment, the Environmental Monitoring Program will focus on the environmental media impacted by the airborne pathway for the anticipated types and quantities of radionuclides released from the facility.

Table 11.0-1. Building and System Designations

System	Designation
Buildings	
MFFF Building	BMF
Aqueous Polishing Area	BAP
Emergency Generator Building	BEG
Safe Haven Buildings	BSH
Secured Warehouse Building	BSW
Standby Generator Building	BSG
MOX Fuel Fabrication Area	BMP
Shipping and Receiving Area	BSR
Reagent Processing Building	BRP
Administration Building	BAD
Technical Support Building	BTS
Aqueous Polishing Units	
Decanning Unit	KDA
Milling Unit	KDM
Recanning Unit	KDR
Dissolution Unit	KDB
Dechlorination and Dissolution Unit	KDD
Purification Cycle	KPA
Solvent Recovery Cycle	KPB
Oxalic Precipitation and Oxidation Unit	KCA
Homogenization Unit	KCB
Canning Unit	KCC
Oxalic Mother Liquor Recovery Unit	KCD
Acid Recovery Unit	KPC
Offgas Treatment Unit	KWG
Liquid Waste Reception Unit	KWD
Waste Organic Solvent	KWS
Automatic Sampling System	KPG
MOX Processing Units – Receiving Area	
UO_2 Receiving and Storage Unit	DRS
UO_2 Drum Emptying Unit	DDP
PuO_2 Receiving Unit	DCP
PuO_2 3013 Storage Unit	DCM
PuO_2 Buffer Storage Unit	DCE
MOX Processing Units – Powder Area	
PuO_2 Can Receiving and Emptying Unit	NDD
Primary Dosing Unit	NDP
Primary Blend Ball Milling Unit	NBX
Final Dosing Unit	NDS
Powder Auxiliary Unit	NXR

Table 11.0-1. Building and System Designations

System	Designation
Scrap Processing Unit	NCR
Jar Storage and Handling Unit	NTM
Homogenization and Pelletizing Units	NPE, NPF
Scrap Ball Milling Unit	NBY
Sintering Units	PFE, PFF
Grinding Units	PRE, PRF
Quality Control and Manual Sorting Unit	PQE
Pellet Repackaging Unit	PAD
Scrap Box Loading Unit	PAR
Green Pellet Storage Unit	PSE
Sintered Pellet Storage Unit	PSF
Scrap Pellet Storage Unit	PSI
Ground and Sorted Pellet Storage Unit	PSJ
Pellet Handling Unit	PML
Pellet Inspection and Sorting Units	PTE
MOX Processing Units – Fuel Rod Process Area	
Rod Cladding and Decontamination Unit	GME, F
Rod Tray Loading Unit	GMK
Rod Decladding Unit	GDE
X-Ray Inspection Units	SXE, SXF
Helium Leak Test Unit	SEK
Rod Inspection and Sorting Unit	SDK
Rod Scanning Unit	SCE
Rod Storage Unit	STK
MOX Processing Units – Assembly Area	
Assembly Mockup Loading Unit	TGM
Assembling Mounting Unit	TGV
Assembly Handling and Storage Unit	TAS
Assembly Dry Cleaning Unit	TCK
Assembly Dimensional Inspection Unit	TCP
Assembly Final Inspection Unit	TCL
Assembly Packaging Unit	TXE
MOX Processing Units – Waste Handling Areas	
Filter Dismantling Unit	VDR
Maintenance and Mechanical Dismantling Unit	VDU
Waste Storage Unit	VDQ
Waste Nuclear Counting Unit	VDT
Mechanical Utility Systems	
HVAC Chilled Water System	CHH
Process Chilled Water System	CHP
Demineralized Water System	DMW
Process Hot Water System	HWS

Table 11.0-1. Building and System Designations

System	Designation
Process Steam and Process Condensate Systems	SPS and SPC
Plant Water System	PWS
Emergency Generator Fuel Oil System	EGF
Standby Generator Fuel Oil System	SGF
Service Air System	SAS
Instrument Air System	IAS
Breathing Air System	BAS
Radiation Monitoring Vacuum System	VRM
Bulk Gas Systems	
Nitrogen System	GNS
Argon/Hydrogen System	GAH
Helium System	GHE
Oxygen System	GOX
Reagent Systems	
Nitric Acid System	RNA
Silver Nitrate System	RSN
Tributyl Phosphate System	RTP
Hydroxylamine Nitrate System	RHN
Sodium Hydroxide System	RSH
Oxalic Acid System	ROA
Diluent System	RDO
Sodium Carbonate System	RSC
Hydrogen Peroxide System	RHP
Hydrazine System	RHZ
Manganese Nitrate System	RMN
Decontamination System	DCS
Uranyl Nitrate System	RUN
Nitrogen Oxide System	GNO
HVAC Systems	
Very High Depressurization Exhaust System	VHD
High Depressurization Exhaust System	HDE
Medium Depressurization Exhaust System	MDE
Process Cell Exhaust System	POE

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11.1 CIVIL STRUCTURAL SYSTEMS

11.1.1 Function

The safety functions of the principal SSCs associated with the civil structural systems are discussed in Chapter 5. Civil structural systems provide the following functions:

- Support principal structures, systems, and components (SSCs) and other SSCs during normal, severe, and extreme loading conditions
- Provide confinement functions as part of secondary and tertiary confinement systems
- Protect principal SSCs from the effects of normal, severe, and extreme environmental loads
- Protect principal SSCs from the effects of design basis internal and external fires by providing fire barriers.

11.1.2 Description

The civil structural systems for the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) include the buildings, support structures, and facilities that house, support, confine, or contain various plant systems, components, and equipment associated with licensed nuclear materials, or hazardous chemicals associated with licensed nuclear materials, as well as support buildings.

The buildings and structures of the MFFF are arranged as shown in Figure 11.1-1. They provide for safe, secure, and efficient performance of all MFFF functions. In particular, the site layout and facility features satisfy stringent security criteria for safeguarding the special nuclear material utilized at the MFFF.

The entire MFFF site comprises an area of approximately 41 ac (16.6 ha). Approximately 17 ac (6.9 ha) of the site are developed with buildings, facilities, or paving. The remaining 24 ac (9.7 ha) are landscaped in either grass or gravel. No highways, railroads, or waterways traverse the MFFF site, and the movement of material and personnel to and from the MFFF site takes place via the Savannah River Site (SRS) internal road system.

A double perimeter intrusion detection and surveillance (PIDAS) fence surrounds the Protected Area (PA) of the MFFF. The PA occupies approximately 14 ac (5.7 ha) and is roughly square in shape. The MFFF Administration Building and the Gas Storage Facility are located outside the PA. The Receiving Warehouse Building, which is located adjacent to the site access road, is an integral part of the outer PIDAS security barrier. All other buildings and facilities of the MFFF lie within the PA.

Three categories of structural design requirements are defined. The categories, loadings, and structures are defined in detail in subsequent sections and are summarized as follows:

- Seismic Category I (SC-I) – Normal, severe, and extreme environmental loads, including the design basis earthquake and tornado, which are applied to principal SSCs.

- **Seismic Category II (SC-II)** – Normal, severe, and extreme loading with extreme loads limited to the design basis earthquake. These loads are applied to structures whose failure could adversely impact principal SSCs (i.e., secondary seismic interaction).
- **Conventional Seismic (CS)** – Normal, severe, and extreme loads with extreme loads limited to conventional seismic loads as specified by the Uniform Building Code.

Table 11.1-1 identifies the structures located at the MFFF site and defines the seismic category classification of each. The following section briefly describes the MFFF buildings and structures and includes conceptual general arrangement drawings.

11.1.3 Major Components

11.1.3.1 MOX Fuel Fabrication Building (BMF, SC-I) (Figures 11.1-2 through 11.1-35)

The MOX Fuel Fabrication Building (BMF) consists of three areas: the MOX Processing Area (BMP), the Aqueous Polishing Area (BAP), and the Shipping and Receiving Area (BSR). The overall roof height of the BMF is a common elevation of 73 ft (22 m) above grade (elevation 346 ft [105 m]). The MOX Processing Area is approximately 285 ft (87 m) by 272 ft (83 m), with three basic floor levels and numerous, smaller, intermediate platforms to accommodate the various process equipment and operations. The Aqueous Polishing Area is approximately 120 ft (37 m) by 175 ft (53 m) with seven basic floor levels. The Shipping and Receiving Area is approximately 120 ft (37 m) by 167 ft (51 m) with three floor levels, except in the Truck Bay Area where there are two levels. The floor level of the MOX Processing Area is at grade (finished floor elevation of 273 ft [83 m]), the base level of the Shipping and Receiving Area has a portion at grade and a portion at 14 ft (4.3 m) below grade (elevation 259 ft [79 m]), and the floor level of the Aqueous Polishing Area is approximately 17.5 ft (5.3 m) below grade (elevation 256 ft [78 m]).

The overall basic structural framing system for the BMF consists of reinforced concrete shear walls, floors, and roof slab. Interior partitions are constructed of reinforced concrete. The roof structure is a flat reinforced concrete slab (details discussed below) with a membrane top. All personnel doors are hollow metal in metal frames. There are a number of special doors for security or function, such as rolling (roll-up) doors, as well as a number of removable wall panels for removal or replacement of processing equipment.

The base mat of the entire MOX Fuel Fabrication Building is nominally 6.5 ft (2 m) thick reinforced concrete. Exterior walls of the MOX Fuel Fabrication Building are reinforced concrete with an additional outer reinforced concrete retaining wall.

[*Text removed under 10 CFR 2.390.]

The structural roof slab of the MOX Fuel Fabrication Building is reinforced concrete with engineered fill material atop the roof slab, which is covered by an additional concrete slab and membrane roofing system (Class A, UL 790 fire rating). This roof system also provides a security function.

11.1.3.2 Emergency Generator Building (BEG, SC-I) (Figure 11.1-37)

The Emergency Generator Building is a single-story (24 ft [7.3 m] inside ceiling height), slab-on-grade reinforced concrete building with a footprint of approximately 44 ft (13 m) by 143 ft (44 m) or 6,300 ft^2 (585 m^2). Heating, ventilation, and air conditioning (HVAC) equipment for the Emergency Generator Building is located on an elevated mezzanine floor located above the switchgear rooms. Air intake and exhaust vents for the diesel generators themselves are in the individual diesel rooms and are geometrically configured to preclude entry of the design basis tornado missile.

11.1.3.3 Emergency Fuel Storage Vault (UEF, SC-I) (Figure 11.1-37)

The UEF is a single-story (19 ft (5.8 m) inside ceiling height vault area and 29 ft (8.8 m) inside ceiling height penthouse area), in-ground buried reinforced concrete building with a footprint of approximately 42 ft (12.8 m) by 64 ft (19.5 m) or 2,700 ft^2 (251 m^2). The walls, floor, and roof are of sufficient strength and thickness to protect against effects of wind and tornado and associated generated missiles, as well as to resist seismic forces due to the design basis earthquake.

11.1.3.4 Safe Haven Buildings (BSH, SC-II) (Included in Figures 11.1-2, -3, and -4)

The five Safe Haven Buildings are located at grade and at the emergency exits from the MOX Fuel Fabrication Building. The safe havens are single-story (10 ft [3 m] inside ceiling height) buildings with variable floor areas that range from 2,100 ft^2 (195 m^2) to 4,500 ft^2 (418 m^2). The same outer security barrier that protects the exterior walls and roof of the MOX Fuel Fabrication Building also protects the exterior walls and roofs of the Safe Haven Buildings.

11.1.3.5 Reagent Process Building (BRP, CS) (Figure 11.1-36)

The Reagent Process Building is a single-story (18 ft [5.5 m] inside roof/ceiling height) building of approximately 10,000 ft^2 (929 m^2). The floor is reinforced concrete slab on grade with a perimeter strip footing adequate for the building loads and soil conditions. The exterior walls and roof are constructed of concrete or metal panels for walls and metal decking for roof.

11.1.3.6 Administration Building (BAD, CS) (Figures 11.1-41 and 11.1-42)

The Administration Building is a two-story, steel-framed structure. The first story is slab on grade, and the second story is lightweight concrete on metal decking and bar joist framing. The exterior walls consist of masonry or modular metal panels with an integrated glazing system. The building has a floor area of approximately 36,000 ft^2 (3,345 m^2).

11.1.3.7 Secured Warehouse Building (BSW, CS) (Figure 11.1-45)

The Secured Warehouse Building is a single-story, slab-on-grade, metal building of approximately 21,200 ft^2 (1,970 m^2) with insulated metal roofing and siding. The Secured Warehouse Building receives and stores the non-nuclear materials, supplies, and equipment received in the PA that are stored onsite for future use. The BSW also provides space for storage of depleted uranium and empty MOX fresh fuel packages. In addition, a small parts washing area is provided for tools and components.

11.1.3.8 Technical Support Building (BTS, CS) (Figures 11.1-43 and 11.1-44)

The Technical Support Building is a two-story, steel-framed building supported on spread footings. The building covers an area of approximately 49,300 ft^2 (4,580 m^2), and the first floor is slab-on-grade. The Technical Support Building is located between the Administration Building and the MOX Fuel Fabrication Building. It provides the main support facilities for MOX Fuel Fabrication Building personnel. It serves as the sole personnel access into and out of the PA access (except for vehicle drivers escorted in and out of the Vehicle Access Portal). Such activities as photo identification, search, and pass-through take place in the personnel access portal in the Access Control Area. The Technical Support Building is not directly involved in the principal processing functions of the MFFF. Supporting activities and facilities located in this building include health physics facilities, an electronics maintenance lab, a mechanical maintenance shop, personnel locker rooms, and a first aid station.

11.1.3.9 Standby Generator Building (BSG, CS) (Figure 11.1-47)

The Standby Generator Building is a single-story, slab-on-grade, metal building, with metal roofing and siding. The building has a footprint of approximately 5,500 ft^2 (511 m^2). The building contains two standby diesel generators. Supporting electrical equipment is located adjacent to the diesel generator rooms and is separated by fire barriers.

11.1.3.10 Receiving Warehouse Building (BRW, CS) (Figure 11.1-46)

The Receiving Warehouse Building is a single-story, slab-on-grade, metal building of approximately 6,200 ft^2 (576 m^2) with insulated metal roofing and siding. The building contains areas for receipt, unpacking, and inspection of material, supplies, and equipment prior to transfer through the PIDAS into the protected area or the BAD. The Vehicle Access Portal (WVA) is located on the south side and adjacent to the BRW and is the access and inspection area for vehicles passing through the PIDAS and entering the PA.

11.1.3.11 Miscellaneous Site Structures (CS)

The miscellaneous site structures include a bulk gas storage pad (Figure 11.1-40), HVAC (Figure 11.1-39) and process chiller pads (Figure 11.1-38), diesel fuel filling station, electric transformer pads, and other minor structures.

11.1.4 Control Concepts

This section is not applicable to buildings and structures.

11.1.5 System Interfaces

Civil structural systems interface with the site and all plant systems because they provide protection and support for SSCs.

11.1.6 Design Basis for Non-Principal SSCs

11.1.6.1 Seismic Category II (SC-II) Structures

11.1.6.1.1 Functions of SC-II Structures

SC-II structures must maintain integrity during the design basis earthquake to avoid adverse impact on principal SSCs.

11.1.6.1.2 Requirements for SC-II Structures

11.1.6.1.2.1 Structural Analysis Requirements for SC-II Structures

SC-II structures are analyzed for the loads and loading combinations identified in Section 11.1.6.1.4.1. Appropriate consideration is given to the load distribution on the structure (e.g., point loads, uniformly distributed loads, or varying distribution of loads) and the end restraint conditions applicable for the structural component being considered.

Analyses may be performed using equivalent static loads, with appropriate consideration of impact effects for moving loads, as specified for the particular loads described in Section 11.1.7.4.1.

11.1.6.1.2.2 Seismic Analysis Requirements for SC-II Structures

The seismic analysis requirements for SC-II structures are the same as specified in Section 11.1.7.4.1.3 (under "Seismic Loads") for SC-I structures.

11.1.6.1.2.3 Structural Design Requirements for SC-II Structures

Design of SC-II Concrete Structures

The design of SC-II concrete structures uses the ultimate strength design methods in accordance with the requirements of ACI-318, *Building Code Requirements for Reinforced Concrete Structures*.

All structural concrete used in construction of SC-II structures has a minimum compressive strength of 4,000 psi. All reinforcing steel used in SC-II structures has a minimum yield strength of 60,000 psi.

The design of post-installed concrete anchor embeds and cast-in-place anchors for SC-II structural applications is in accordance with the requirements of ACI 349-01, Appendix B, Anchoring to Concrete. Post-installed concrete anchors for SC-II structural application are the undercut type.

Design of SC-II Steel Structures

SC-II steel structures are designed in accordance with AISC ASD, *Manual of Steel Construction, Allowable Stress Design, and Supplement 1*. Elastic design methods are generally used for steel design. However, under extreme loading conditions, plastic design methods may be used.

11.1.6.1.2.4 Foundation Design Requirements for SC-II Structures

The allowable soil bearing capacity for SC-II foundation design is based on SC-I allowable soil bearing pressure as presented in Section 11.1.7.2.2.3. Foundations for SC-II structures are designed in accordance with the appropriate requirements of Section 11.1.6.1.2.3.

11.1.6.1.3 Codes and Standards for SC-II Structures

Codes and standards applied to the MFFF SC-II structures are the same as those specified in Section 11.1.7.3, except the following are not applicable:

- ACI-349-97, *Code Requirements for Nuclear Safety-Related Concrete Structures & Commentary*
- ACI-349.1R-91, *Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures*, Reapproved 1996
- ACI-349.2R-97, *Embedment Design Examples*
- ANSI/AISC N690-1994, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, and Supplement 1, dated 4/15/02.*

In addition to the codes and standards specified in Section 11.1.7.3, the following code is applicable to SC-II structures:

- ACI-318-99, Building Code Requirements for Reinforced Concrete Structures & Commentary.

11.1.6.1.4 Values for SC-II Structures

11.1.6.1.4.1 Structural Design Loads for SC-II Structures

Design loads are based upon anticipated building loads (i.e., dead loads, live loads, operating and transient loads, and natural phenomena hazard loads). These loads are divided into three classifications (normal loads, severe environmental loads, and extreme environmental loads) as specified in Section 11.1.7.4, except the only extreme environmental load considered is the design basis earthquake (E'). The MFFF site design criteria are summarized in Table 11.1-2. The structures located at the MFFF site, along with their seismic category classification, are provided in Table 11.1-1.

11.1.6.1.4.2 Loading Combinations for SC-II Structures

Loading combinations for the design of SC-II structures and facilities are the same as the loading combinations for SC-I structures, as specified in Section 11.1.7.4, except the only extreme environmental load considered is the design basis earthquake (E'). Also, for concrete structures, "U" is the section strength required to resist design loads based upon the ultimate strength design methods described in ACI 318, *Building Code Requirements for Reinforced Concrete*. For steel structures, "S" is the required section strength based on elastic design methods and the allowable stresses defined in AISC Specification for Structural Steel Building and Supplement 1, Allowable Stress Design and Plastic Design.

structure to missile impact depends largely on the location of impact on the structure, on the material properties of the structure, on the dynamic properties of the missile, and on the kinetic energy of the missile. Both the local and overall effects of missile impact are examined, with appropriate consideration given to impact effects of the loading. Some localized overstressing, deformation, and damage are permissible for structures subjected to missile impact. It is acceptable to allow inelastic or plastic structural response when examining the effects of missile impact.

The modified National Defense Research Committee formula, as specified in ASCE 58, *Structural Analysis and Design of Nuclear Plant Facilities*, is used to estimate missile penetration. The missile barrier thickness is selected to preclude perforation through the concrete barrier and to avoid generation of secondary missiles as a result of scabbing.

The overall effects of missile impact on a structural system are investigated to ensure that the structure retains its integrity and functionality subsequent to a missile strike. One missile impacting a structure at any given time is considered.

11.1.7.2.2 Structural Design Requirements for SC-I Structures

11.1.7.2.2.1 Structural Design Requirements for SC-I Concrete Structures

The design of SC-I concrete structures uses the "ultimate strength design methods" in accordance with ACI-349-97, *Code Requirements for Nuclear Safety-Related Concrete Structures.*

All structural concrete used in construction of SC-I structures has a minimum compressive strength of 4,000 psi. All reinforcing steel used in SC-I structures has a minimum yield strength of 60,000 psi.

One exception is taken to ACI 349-97.

The exception to ACI-349-97, Appendix B, is as follows: The design of SC-I embedded plates, cast-in place anchors, and post-installed concrete anchors is in accordance with the requirements of ACI 349-01, Appendix B, *Anchoring to Concrete.* Post-installed concrete anchors for SC-I structural applications are undercut type.

11.1.7.2.2.2 Structural Design Requirements for SC-I Steel Structures

SC-I steel structures are designed in accordance with AISC N690, *Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities and Supplement 1.* Elastic design methods are generally used for steel design. However, under the extreme loading conditions of seismic or missile impact loading, plastic design methods and use of ultimate steel strength may be used.

Structural steel connections can be designed as either friction or bearing type bolted connections or welded connections. Bolted connections are designed in accordance with AISC N690 and *Specification for Structural Joints Using ASTM A325 or A490 Bolts.* Welded connections are designed in accordance with AISC N690, AWS D1.1, *Structural Welding Code, and AWS D1.6, Structural Welding Code - Stainless Steel.*

The requirements of AISC N690 are supplemented by the following provisions:

- The following note is added to Section Q1.3:

  "Where the structural effects of differential settlement are present, they are included with the dead load 'D'."

- The stress limit coefficients for compression in Table Q1.5.7.1 are as follows:
  - 1.3 instead of 1.5, stated in footnote (C), in loading combinations 2, 5, and 6
  - 1.4 instead of 1.6 in loading combinations 7, 8, and 9
  - 1.6 instead of 1.7 in loading combination 11.

- The following note is added to Section Q1.5.8:

  "For constrained (rotation and/or displacement) members supporting safety related structures, systems, or components, the stresses under loading combinations 9, 10, and 11 are limited to those allowed in Table Q1.5.7.1 as modified by provision above. Ductility factors of Table Q1.5.8.1 (or the provision below) is not used in these cases."

- For ductility factors 'μ' in Sections Q1.5.7.2 and Q1.5.8, the provisions of NUREG-0800, Section 3.5.3, "Barrier Design Procedures," Subsection II.2, Appendix A, are substituted in lieu of Table Q1.5.8.1.

- In loading combination 9 of Section Q2.1, the load factor applied to load P_a is 1.5/1.1 = 1.37, instead of 1.25.

- Sections Q1.24 and Q1.25.10 are supplemented with the following requirements regarding painting of structural steel:
  - Shop painting is in accordance with Section M3 of AISC ASD, 9th Edition.
  - All exposed areas after installation are field painted (or coated) in accordance with the applicable Section M3 of AISC ASD, 9th Edition.
  - The quality assurance requirements for painting (or coating) of structural steel are in accordance with ANSI N101.4 as endorsed by Regulatory Guide 1.54, *Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants.*

Welding activities associated with SC-I structural steel components and their connections are accomplished in accordance with written procedures and meet the requirements of AWS D1.1 or AWS D1.6. The visual acceptance criteria are as defined in NCIG-01.

11.1.7.2.2.3 Foundation Design Requirements for SC-I Structures

The minimum factor of safety against bearing capacity failure due to static loads (dead loads + normal live loads, such as equipment loads) is 3.0. The minimum factor of safety for static loads + severe environmental loads, such as design wind, is 1.5, and for static loads + extreme environmental loads, such as seismic loads due to the design earthquake or wind loads due to the design tornado, is 1.1. In addition, the SC-I structures are designed for differential settlement, as applicable.

For evaluation of subsurface conditions, to include liquefaction and post-earthquake settlements, bedrock motions based upon a 2,000-year recurrence frequency bedrock spectrum are used, scaled so that when amplified through the site soil profile, the resulting surface ground motion will have 0.20g peak ground acceleration. A settlement monitoring program is implemented for SC-I structures. Settlement monuments are provided to track total and differential settlement. Actual versus predicted settlement is evaluated.

11.1.7.3 Codes and Standards for SC-I Structures

Codes and standards applied to the MFFF include the following:

American Concrete Institute (ACI)

- ACI-224R-90, *Control of Concrete Cracking in Concrete Structures*
- ACI-301-99, *Standard Specifications for Structural Concrete*
- ACI-315-99, *Details and Detailing of Concrete Reinforcement*
- ACI-336.2R-88, *Suggested Analysis and Design Procedures for Combined Footings and Mats*
- ACI-349-97, *Code Requirements for Nuclear Safety-Related Concrete Structures & Commentary*
- ACI-349.1R-91, *Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures*, Reapproved 1996
- ACI-351.1R-99, *Grouting for Support of Equipment & Machinery*
- ACI-352R-91, *Recommendations for Design of Beam-Column Joints in Monolithic Reinforced Concrete Structures*, Reapproved 1997
- ACI-352.1R-89, *Recommendations for Design of Slab-Column Connections in Monolithic Reinforced Concrete Structures*, Reapproved 1997
- ACI-349-01, Appendix B, *Anchoring to Concrete* (for anchoring to concrete only)
- ACI-360R-92, *Design of Slabs on Grade*, Reapproved 1997
- ACI-351.2R-94, *Foundations for Static Equipment*
- ACI-439.3R-91, *Mechanical Connections of Reinforcing Bars*
- ACI-SP-152-95, *Design and Performance of Mat Foundations*

- ACI-503R-93, *Use of Epoxy Compounds with Concrete*
- ACI-442-88, *Response of Concrete Buildings to Lateral Forces*
- ACI-207.1R-96, *Mass Concrete*
- ACI-207.2R-95, *Effect of Restraint, Volume Change, and Reinforcement on Cracking of Mass Concrete*
- ACI-207.4R-93, *Cooling and Insulating Systems for Mass Concrete.*

American Institute of Steel Construction (AISC)

- AISC *Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design, June 1, 1989, and Supplement 1, dated December 17, 2001*
- ANSI/AISC N690-1994, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities*
- AISC, *Seismic Provisions for Structural Steel Buildings*, April 1997
- AISC, *Connections Manual for Hollow Structural Sections*, 1997

American Society of Civil Engineers (ASCE)

- ASCE Standard 4-98, *Seismic Analysis of Safety Related Nuclear Structures*
- ASCE Standard 7-98, *Minimum Design Loads for Buildings and Other Structures*
- ASCE Standard 8-91, *Specification for the Design of Cold-Formed Stainless Steel Structural Members*
- ASCE Standard 58-80, *Structural Analysis and Design of Nuclear Plant Facilities.*

American Welding Society (AWS)

- AWS-D1.1-98, *Structural Welding Code – Steel*, 1998
- NCIG-01, *Visual Weld Acceptance Criteria for Structural Welding of Nuclear Power Plants*, Revision 2, EPRI NP-5380
- AWS-D1.6-99, *Structural Welding Code – Stainless Steel*, 1999.

American Association of State Highway and Transportation Officials (AASHTO)

- *Standard Specifications for Highway Bridges*, Sixteenth Edition, 1996.

American National Standards Institute (ANSI)

- ANSI N101.4, *Quality Assurance for Protective Coatings Applied to Nuclear Facilities*, 1972.

American Iron and Steel Institute (AISI)

- AISI, *Specifications for the Design of Cold-Formed Steel Structural Members*, 1986.

American Society for Testing and Materials (ASTM)

- Research Council on Structural Connections, *Specification for Structural Joints Using ASTM A325 and A490 Bolts*, June 23, 2000.

Code of Federal Regulations (CFR)

- 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*
- 10 CFR Part 73, *Physical Protection of Plants and Materials.*

SRS Engineering Standards Manual (WSRC-TM-95-1)

- Engineering Standard No. 01060, *Structural Design Criteria*, Revision 4, dated September 1999
- Engineering Standard No. 01110, *Civil Site Design Criteria*, Revision 3, dated April 11, 2000.

U.S. Nuclear Regulatory Commission (NUREG)

- NUREG-0800, Standard Review Plan 3.5.3, *Barrier Design Procedures*, July 1981
- NUREG-0800, Standard Review Plan 3.8.4, *Other Seismic Category I Structures*, July 1981
- NUREG-0800, Standard Review Plan 3.5.1.6, *Aircraft Hazards*, April 1996.

11.1.7.4 Loads and Loading Combinations for SC-I Structures

11.1.7.4.1 Structural Design Loads for SC-I Structures

Design loads are based upon anticipated building loads (i.e., dead loads, live loads, operating and transient loads, and natural phenomena hazard loads). These loads are divided into three classifications (normal loads, severe environmental loads, and extreme environmental loads) consistent with the guidance provided in NUREG-0800, Section 3.8.4, "Other Seismic Category I Structures." MFFF site design criteria are summarized in Table11.1-2. The structures located at the MFFF site, along with the seismic category classification, are provided in Table 11.1-1.

11.1.7.4.1.1 Normal Loads

Normal loads are those loads associated with normal operation of the MFFF. Normal loads include the following: dead loads (D); live loads (L); hydrostatic fluid pressure loads (F); lateral soil pressure loads (H); thermal loads (T_o); and pipe, HVAC duct, conduit, and cable tray reaction loads (R_o). These loads are defined in the following subsections.

Dead Loads

Dead loads (D) are gravity loads and are defined as any loads, including related internal moments and forces, that are constant in magnitude, orientation, and point of application. Dead loads include the mass of the structure, any permanent equipment loads, and any permanent hydrostatic loads that have constant fluid levels. The weight of permanent items (e.g., roofing materials, including insulation and engineered fill, wall materials, equipment, cable trays, mechanical piping, and HVAC equipment and ducts) is included in the dead load. When determining dead loads, the effects of differential settlement are considered.

Actual equipment loads are applied to the design of structural systems and components. In addition, unless specifically reviewed, a minimum uniform dead load is applied to all elevated floors, platforms, roof areas, walls, and floor slabs to account for miscellaneous equipment loads, piping, cable trays, conduits, and HVAC ducts. (A uniform dead load of 25 psf is applied to all wall surfaces, i.e., a total of 50 psf on each wall panel. Also, 25 psf is applied to the underside of all elevated floor slabs and roof slabs to account for miscellaneous attachments. A uniform dead load of 50 psf is applied to platforms.) The following dead load shall be applied:

• Bottom of elevated slabs, roof, and platform	50 psf
• 12 in and 18 in walls	50 psf

Live Loads

Live loads (L) are defined as any normal loads, including related internal moments and forces, that may vary with intensity, orientation, and/or location of application. Movable equipment loads, loads caused by vibration, any support movement effects, and operating loads are types of live loads. The following subsections provide design requirements for the various types of live loads.

Floor Live Loads

Minimum uniformly distributed live loads are in accordance with ASCE Standard 7 and are applied as follows:

Platform and Work Area	125 psf
Light Storage	125 psf
Heavy Storage	250 psf
Heavy Operation	250 psf
Office	100 psf
Computer Room	150 psf
Dining/Meeting Rooms	100 psf
Laboratory	200 psf
Toilet Areas	100 psf
Mechanical (Utility) Rooms	150 psf
Electrical Rooms	150 psf
Stairs, Fire Escapes, and Corridors	100 psf
Transportation Vehicle Loads	300 psf or forklift truck, 6 kip capacity (HS20-44 capacity in designated areas)

Roof	50 psf, ASCE Standard 7, Table 4-1 (This load does not combine with the rain load, 50 psf, on the roof concurrently)

Rain Loads

Rain loads (R) are determined in accordance with the requirements of ASCE Standard 7, Section 8. The roof system for SC-I structures is designed for a minimum rain load of 50 psf. The design load of 50 psf is equal to more than 9.6 in. (24.4 cm) in equivalent weight of standing water and is adequate to account for any effects that may result from ponding of rainwater due to deflection of the supporting roof or the blockage of primary roof drains. This design load of 50 psf is equivalent to 9.6 in. (24.4 cm) accumulation of precipitation over a period of 1 hour and 39 minutes based on a linear interpolation of the data. Parapets or other structures, which may potentially contribute to significant ponding, are not used on the roofs of SC-I structures. The rain load is not applied concurrently with the roof live load.

Snow and Ice Loads

Snow (S) and ice (I) loads are determined in accordance with Table 11.1-2. The minimum design live load due to snow and ice is 10 psf. This load is applied concurrently with the roof live load. An exposure factor of $C_e = 1.0$ is used to consider wind effects for analysis and design of roof structures resisting snow and ice loads. An importance factor of $I = 1.2$ is used for SC-I structures.

Transportation Vehicle Loads and Heavy Floor Loads

Loads caused by transportation vehicular truck traffic in designated building areas are in accordance with standard loadings defined by AASHTO. The minimum truck loading of HS 20-44 is used for wheel loading design. Special heavy-loading conditions resulting from transport of finished fuel assemblies and storage casks on trucks are considered. Heavy floor loading of 300 psf or forklift truck (6 kip capacity) in areas used for transportation, transfer, and storage of finished fuel assemblies is considered.

Crane, Monorail, Hoist, and Elevator Loads

These loads apply to structural members and components required to support permanently installed cranes, monorail, hoists, and elevators. Design loads for cranes, monorail, hoists, and elevators envelop, as a minimum, the full-rated capacity of the crane, monorail, hoist, and elevator including impact loads, as well as test load requirements. The effects of crane load drop are also evaluated in accordance with guidance provided in NUREG-0612, *Control of Heavy Loads at Nuclear Plants*, for SC-I structures.

Hydrostatic Fluid Pressure Loads

Hydrostatic fluid pressure loads (F) are due to fluids held in internal building compartments. No fluid pressure loads are currently identified for the MFFF.

Lateral Soil Pressure Loads

Lateral soil pressure loads (H) on structures and/or elements of structures retaining soil are based on the density of the soil and any surcharge load, plus the hydrostatic pressure caused by the groundwater or soil saturation. The minimum lateral soil pressure loads on structures and/or elements of structures retaining soil are as defined in ASCE Standard 7, Section 5. The soil pressure caused by earthquakes based on ASCE Standard 4 is included. The groundwater table is below MFFF structures; therefore, no hydrostatic pressure caused by groundwater and flooding is anticipated on building structures. If groundwater is encountered, the loads on structures and/or elements of structures caused by uplift or additional load due to saturated material are considered in design.

Thermal Loads

Thermal loads (T_o) consist of thermally induced forces and moments resulting from operation and environmental conditions affecting the building structure. Thermal loads are based on the most critical transient or steady-state condition. Thermal expansion loads caused by axial restraint, as well as loads resulting from thermal gradients, are considered. Thermal loads considered include the ambient temperature gradient imposed on the structure by process equipment.

Pipe, HVAC Duct, Conduit, and Cable Tray Reaction Loads

Pipe, HVAC duct, conduit, and cable tray reaction loads (R_o) are those loads applied by distribution system supports during normal operating conditions, based on the most critical transient or steady-state condition. The design allowance to address these loads is defined in Section 11.1.7.4.1.1, Dead Loads. Loads are tracked to ensure that the final design envelops actual loads.

11.1.7.4.1.2 Severe Environmental Loads

Severe environmental loads are those loads that are encountered infrequently during the life of the MFFF. They include wind loads (W) and flood loads (F'). These loads are defined in the following subsections.

Wind Loads

Wind loads (W) are those pressure loads generated by the design basis wind and are determined by procedures in ASCE Standard 7, Section 6. The severe wind speed, defined in Table 11.1-2, is used in the design of SC-I buildings, structures, and facilities.

Flood Loads

Flood loads (F') are caused by exterior flood waters from the design basis flood exerting forces and moments on exterior building structures or entering a building and exerting loads on interior building structures. Flood loads on building, structures, and facilities are determined in accordance with ASCE Standard 7, Section 5.3. Guidance for determining the design basis flood is provided in Regulatory Guide 3.40, *Design Basis Floods for Fuel Reprocessing Plants and for Plutonium Processing and Fuel Fabrication Plants*. As shown in Table 11.1-2, the design basis flood and probable maximum flood elevations are well below the MFFF site elevation. Thus, flood loads are not applicable to the MFFF.

11.1.7.4.1.3 Extreme Environmental Loads

Extreme environmental loads are those loads that are credible but are not expected to occur during the life of the MFFF. They include seismic loads (E'), tornado loads (W_t), explosive loads, and loads due to post-earthquake settlements. These loads are defined in the following subsections. (Note: As described in Section 5.5.1, the possibility of aircraft impact is not a credible event; thus, aircraft impact is not a design basis event.)

Seismic Loads

Design Basis Earthquake Loads for SC-I Structures

In accordance with the guidance of Regulatory Guide 3.14, *Seismic Design Classification for Plutonium Processing and Fuel Fabrication Plants*, and DOE-STD-1020-94, *NPH Design and Evaluation Criteria for DOE Facilities*, all SC-I buildings, structures, and facilities at the MFFF are designed to accommodate a design basis earthquake.

The design basis earthquake for the MFFF is defined in Section 1.3.6 and summarized in Table 11.1-2. Design basis earthquake loads (E') for SC-I and SC-II buildings, structures, and facilities are determined based upon a horizontal component at the ground surface characterized by a horizontal spectrum shape from Regulatory Guide 1.60, *Design Response Spectra for Seismic Design of Nuclear Power Plants*, scaled to 0.20g peak ground acceleration. The vertical component is the vertical spectrum shape from Regulatory Guide 1.60 scaled to 0.20g peak ground acceleration. Methods used for the soil-structure interaction (SSI) determining seismic responses from these acceleration input criteria conform to NUREG-0800, Sections 3.7.1 and 3.7.2 and the requirements of ASCE Standard 4.

Total seismic loads affecting a structure are determined by simultaneously applying the design basis earthquake accelerations in the three orthogonal directions (two horizontal and one vertical). Appropriate consideration of SSI, torsional effects, structural frequency, stiffness, and displacement is factored into structure-specific seismic load analyses. The SSI analyses for the SC-I MOX Fuel Fabrication Building and Emergency Generator Building are performed on simplified stick models representing the building characteristics (e.g., mass, rigidity, center of mass, and center of rigidity) using the computer code SASSI (Framatome-ANP DE&S version). From the SSI analysis, the response spectra at the foundation and each floor and roof level are obtained for building and equipment design and acceleration profile for building design.

Synthetic Time History of Free-Field Seismic Motion

Three components of the synthetic time histories for the design basis earthquake seismic motion are generated to closely match the design basis earthquake. The three components of the synthetic time histories are statistically independent of each other. The response spectrum of each component of time history motion envelops the design spectrum in accordance with the enveloping criteria in NUREG-0800, Section 3.7.1, "Seismic System Analysis." In addition, each horizontal component of time history meets the minimum power spectral density requirement specified in NUREG-0800, Section 3.7.1, Appendix A.

Soil Model

In the SSI analysis, the soil model consists of a sufficient number of idealized soil layers from the ground surface to the bedrock. The thickness of each soil layer is small enough to allow vertical propagation of shear waves having frequencies up to the desired cutoff frequencies. The properties of the idealized soil layers are developed based upon the information provided by the soil exploration report and site response analysis. Variations in soil properties are considered.

Structure Models

A detailed 3D finite element model (FEM) using standard computer structural modeling codes (e.g., ANSYS) is first generated based on the structural drawings. In addition to all applicable dead weights and equipment weights, the FEM includes appropriate parts of the live loads (25% of the applicable live loads, which shall be verified during design) in the mass properties of the model for seismic analysis.

A simplified 3D finite element model is generated from the detailed 3D model based on coarser mesh. The simplified 3D finite element model is used for the SSI analysis of the BMF (e.g., integrated structures of the MOX Processing Area (BMP), Aqueous Polishing Area (BAP), Shipping and Receiving Area (BSR)). The simplified model assumes that all slabs are uncracked. The embedment of BAP and BSR is very shallow compared to the plan dimensions of BMF, and is ignored in the SSI analysis.

For the BEG, a 3D lumped-mass stick model is generated for use in the SSI analysis.

Damping Values for Structures

When determining seismic loading, the types of structural materials and construction practices utilized shall be considered. The following structural damping values, which are in accordance with Regulatory Guide 1.61, *Damping Values for Seismic Design of Nuclear Power Plants* (Reference 3.17), for a safe shutdown earthquake (design basis earthquake, E'), are used to determine seismic loading:

Structure Type	% of Critical Damping
Welded Steel	4
Bolted Steel	7
Reinforced Concrete	7

In-Structure Response Spectrum Envelope with Peak Broadening

In each of the three directions (north-south, east-west, and vertical) and at each given structural location, the in-structure response spectra from the 3D SSI analysis of the simplified finite element model of the BMF and the stick model of the BEG for the lower-bound, best-estimate, and upper-bound soil conditions are first broadened. For the BMF, a broadening of the in-structure response spectrum peak(s) by -25% and +15% is applied to the best-estimate soil condition and by -20% and +10% to the lower-bound and upper-bound soil conditions for the horizontal spectra. The corresponding peak-broadening for the vertical spectra is -15% and +15% for the best-estimate soil condition and by -10% and +10% to the lower-bound and upper-bound soil conditions. For the BEG, the in-structure response spectrum peaks are broadened by -15% and +15% for all three soil conditions and in all three directions. The peak-broadened spectra from the three soil conditions are then enveloped. At each floor, the response spectra at the center of mass, plus four corners of the building, are enveloped to conservatively account for the effect of torsion between the center of rigidity and the location of any equipment. Floor flexibility, where applicable, is accounted for in the generation of the vertical in-structure response spectra. Wall flexibility is also accounted for in the generation of the horizontal in-structure response spectra. The peak-broadened in-structure spectrum envelope is for the seismic design of safety related equipment, components, and systems.

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Acceleration Profile Envelope for Static Analysis of 3D FEM of Structure

An acceleration profile in each of the north-south, east-west, and vertical directions is developed from the 3D SSI analysis of the simplified finite element model. In each given direction, the acceleration profiles from the lower-bound, best-estimate, and upper-bound soil conditions are enveloped. The acceleration profile envelope is applied as a static load to the 3D FEM of the BMF, UEF, and BEG for the design of structural elements.

Combination of Seismic Response Components

Two approaches may be used to combine seismic loads in the three orthogonal directions for the building analysis and design. The first approach applies the equivalent accelerations for each level from the SSI analysis to the building FEM statically for each direction. This approach is used for the MOX Fuel Fabrication Building and Emergency Generator Building. In this approach, the equivalent accelerations are determined to ensure that the resulting global structural forces (shear and axial forces) at each level match those from the SSI analysis of the simplified FEM model of the structure. The results from the equivalent static analyses due to the equivalent accelerations applied in the three directions may be combined using the 100-40-40 Percent Rule, described in Section 3.2.7.1.2 of ASCE Standard 4, to determine the resultant design basis earthquake loads on structural components. When combining forces and moments using the 100-40-40 Percent Rule, participation factors of 100% in the primary load direction and 40% in the other two directions are applied to the individual loads, as permitted by ASCE Standard 4.

The second approach applies the applicable seismic response spectrum to the base of the structural model. This approach may be used for other structures. Each of the three directional components of the design basis earthquake produces responses in a structure in all three directions (i.e., three responses in the x direction, three in the y direction, and three in the z direction). Guidance provided by Regulatory Guide 1.92, *Combining Modal Responses and Spatial Components in Seismic Response Analysis*, and ASCE Standard 4 is used for combining modal responses and collinear responses from the three individual earthquake components. Modal responses due to each of the three individual earthquake components may be combined using the SRSS method. Any responses from modes that are clustered within a 10% frequency range may be combined by the absolute sum method in accordance with Regulatory Guide 1.92, and then the remaining responses can be combined by the SRSS method. A sufficient number of modes are considered such that the accumulated modal mass exceeds 90% of the mass of the component. After modal responses are combined to obtain one set in each of the three orthogonal directions, the collinear responses due to contributions from all three earthquake components are combined by the SRSS method.

The following examples show formulas for determining the seismic load force in the x direction using the two methods:

100-40-40 Percent Rule

$$\Sigma F_x = \Sigma 100\%\ F_{x \text{ due to } Ex} + \Sigma 40\%\ F_{x \text{ due to } Ey} + \Sigma 40\%\ F_{x \text{ due to } Ez} \qquad (11.1\text{-}1)$$

SRSS Method

$$\Sigma F_x = (\Sigma F_{x\ \mathrm{due\ to\ Ex'}}{}^2 + \Sigma F_{x\ \mathrm{due\ to\ Ey'}}{}^2 + \Sigma F_{x\ \mathrm{due\ to\ Ez'}}{}^2)^{1/2} \qquad (11.1\text{-}2)$$

Dynamic Lateral Soil Pressure for Embedded Wall Design

The dynamic lateral soil pressures are determined based on the guidelines of ASCE Standard 4.

Tornado Loads for SC-I Structures

Tornado loads (W_t) are those loads generated by the design basis tornado for the MFFF. They include tornado wind pressure loads (W_w), tornado-created differential pressure loads (W_p), and tornado-generated missile loads (W_m). The tornado loads are defined in Section 1.3.3 and summarized in Table 11.1-2. The three types of tornado loads on MFFF structures and facilities are defined in the following subsections.

Tornado Wind Pressure Loads

Tornado wind pressure loads (W_w) are those pressure loads generated by the tornado wind velocity, which is the combined translational and rotational wind speed, as defined in Table 11.1-2. ASCE Standard 7, Section 6 is used to convert tornado wind velocity into effective structural pressure loads.

Tornado-Created Differential Pressure Loads

Tornado-created differential pressure loads (W_p) are those loads acting as an internal pressure loading on structures caused by the negative pressure created by the tornado. The design pressure drop and the rate of pressure drop are defined in Table 11.1-2. This internal pressure is applied to the interior surfaces of all exterior building walls and roofs of structures requiring design against the effects of a tornado. Some reduction in this pressure differential may be allowed for structures that are vented, as permitted by NUREG-0800, Section 3.3.2, "Tornado Loadings."

Tornado-Generated Missile Loads

Tornado-generated missile loads (W_m) are impact loads applied to structures caused by strikes by the missile spectra criteria specified in Table 11.1-2. The provisions of NUREG-0800, Section 3.5.3, Subsection II, ACI 349, Appendix C, and AISC N690 are considered for determining the missile loading on various types of structures.

Explosive Loads for SC-I Structures

Explosions could impact the BMF (including Vent Stack), BEG, UEF, Tornado Missile Barriers, HVAC Intakes, or QL-1 Buried Structures (i.e., Buried Conduit Banks, Waste Line, and Buried Pipes) operations by either structural damage or loss of control room habitability; either impact could result in a release of hazardous material. Identification of bounding external explosion hazard events and establishment of bounding overpressure consequences are determined. Also, results of SRS facility explosions, SRS transportation explosions, MFFF transportation hypothetical explosions, and BRP hypothetical explosions are used to determine the impact of the bounding explosion on the BMF (including Vent Stack), the BEG, the UEF, and other QL-1 components.

Design requirements for impulsive-pressure waves associated with explosive loads are based on ASCE Publication 58, ASCE, *Design for Physical Security, State of the Practice*, and ACI SP-175, Concrete and Blast Effects.

Aircraft/Helicopter Impact for SC-I Structures

The aircraft screening analysis, including helicopters, is performed according to NUREG-0800, *Standard Review Plan*, SRP 3.5.1.6, "Aircraft Hazards," to determine the likelihood of an aircraft accident for the MOX Fuel Fabrication Building (BMF), Emergency Fuel Storage Vault (UEF), and Emergency Generator Building (BEG). It is concluded that the possibility of an aircraft/helicopter accident is highly unlikely during the life of the facility; thus, aircraft/helicopter impact is not evaluated as a design basis event for the Safety Assessment. Potential acts of terrorism are covered by the MFFF Safeguards and Security program and are outside the scope of this Safety Assessment.

Range Fires for SC-I Structures

Protection of SC-I, QL-1a buildings from exterior exposure fires is in accordance with industry standards. A compliance verification review in accordance with NFPA 80A concluded that the hazards presented by range fires to the MFFF are minimized by the site layout, and the MFFF structures will not be adversely impacted by the effects of such fires. Thus, range fires are not a design basis event for these structures.

Post-Earthquake Settlements

The post-earthquake settlements due to the dissipation of excess pore pressures that may occur at depth due to shaking caused by the design earthquake are estimated using 1886 Charleston (50th percentile) motion.

11.1.7.4.2 Structural Design Loading Combinations for SC-I Structures

The following loads are addressed in the loading combinations used for the design of SC-I structures at the MFFF.

D = dead load
L = live load
F = hydrostatic fluid pressure load
H = lateral soil pressure load
T_o = thermal load
R_o = pipe, HVAC duct, conduit, and cable tray reaction load
W = wind load
E' = design basis earthquake seismic load

W_t = tornado loads including:
  W_w = tornado wind pressure load
  W_p = tornado-created differential pressure load
  W_m = tornado-generated missile load
T_a = thermal load (due to postulated break and including T_o)
R_a = pipe reaction (due to postulated break under thermal condition and including R_o)
S_{pe} = post-earthquake settlement.

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Loading combinations for the design of SC-I structures are determined using NUREG-0800, Section 3.8.4, "Other Seismic Category I Structures," as a guide. Since there are no operating basis earthquake loads (E), flood loads (F'), compartmental pressure loads (P_a), or pipe break accident loads (Y_r, Y_j, or Y_m) applicable to the MFFF, these loads, although specified in NUREG-0800, Section 3.8.4, are not included in above list of loads or the loading combinations that follow.

The following definitions apply to terms used in the loading combinations specified in this section:

- For concrete structures, "U" is the section strength required to resist design loads based upon the ultimate strength design methods described in ACI 349, *Code Requirements for Nuclear Safety-Related Concrete Structures* (SC-I).
- For steel structures, "S" is the required section strength based on elastic design methods and the allowable stresses defined in Part 1 of AISC N690, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities* (SC-I), and Supplement 1.
- For steel structures, "Y" is the section strength required to resist design loads based on the plastic design methods defined in Part 2 of AISC N690 (SC-I).

11.1.7.4.2.1 Loading Combinations for SC-I Concrete Structures

The following loading combinations are used for the design of SC-I concrete structures. These loading combinations are used in conjunction with the ultimate strength design method for concrete design. Two conditions of structural loading are considered: (1) service loading conditions, and (2) extreme loading conditions.

Service Loading Combinations for SC-I Concrete Structures

Service loading combinations represent the loading conditions that SC-I structures are expected to experience during normal facility operations and during severe environmental conditions. Loads included in the service loading combinations are dead loads, live loads, hydrostatic fluid pressure loads, lateral soil pressure loads, design wind loads, flood loads, thermal loads, and reaction loads (pipe, HVAC, and/or cable tray). No seismic loads are included in the MFFF service loading combinations.

SC-I concrete structures are designed for the following service loading combinations:

$$U = 1.4D + 1.4F + 1.7L + 1.7H$$

$$U = 1.4D + 1.4F + 1.7L + 1.7H + 1.7W$$

$$U = 1.2D + 1.2F + 1.7W$$

If stresses caused by T_o and/or R_o are present on the structure, the following loading combinations are also considered:

$$U = 1.05D + 1.05F + 1.275L + 1.275H + 1.275T_o + 1.275R_o$$

$$U = 1.05D + 1.05F + 1.275L + 1.275H + 1.275W + 1.275T_o + 1.275R_o$$

Extreme Loading Combinations for SC-I Concrete Structures

Extreme loading combinations represent the loading conditions that SC-I structures could experience under extreme environmental conditions. Loads included in the extreme loading combinations are dead loads, live loads, thermal loads, reaction loads (pipe, HVAC, and cable tray), design basis earthquake seismic loads, tornado loads, and flood loads. Extreme environmental loads (i.e., seismic and tornado loadings) are not considered to act simultaneously.

SC-I concrete structures are designed for the following extreme loading combinations:

$U = D + F + L + H + T_o + R_o + E'$

$U = D + F + L + H + T_o + R_o + W_t$ (see Note 1 below)

$U = D + F + L + H + E' + T_a + R_a$ (see Note 2 below)

$U = D + L + S_{pc}$

Note 1: In accordance with NUREG-0800, Section 3.3.2, Subsection II.3.d, the following combinations of W_t are considered:

$W_t = W_w$
$W_t = W_p$
$W_t = W_m$
$W_t = W_w + 0.5W_p$
$W_t = W_w + W_m$
$W_t = W_w + 0.5W_p + W_m$

Note 2: $T_a = T_o$ and $R_a = R_o$, since pipe break accident loads are not applicable.

11.1.7.4.2.2 Loading Combinations for SC-I Steel Structures

The following loading combinations are used for the design of SC-I steel structures. Applicable combinations are given for designs that utilize either elastic working stress design methods or plastic design methods. In each case, loading combinations are provided for service loading conditions and for extreme loading conditions.

Service Loading Combinations for SC-I Steel Structures

Service loading combinations for SC-I steel structures encompass the same type loads as included for service loading combinations for SC-I concrete structures in Section 11.1.7.4.2.1.

Service Loading Combinations for Elastic Working Stress Design

If elastic working stress design methods are used, SC-I steel structures are designed for the following service loading combinations:

$S = D + F + L + H$

$S = D + F + L + H + W$

If stresses due to T_o and/or R_o are present on the structure, the following loading combinations are also considered:

$(1.5)S = D + F + L + H + T_o + R_o$ (tension members)

$(1.3)S = D + F + L + H + T_o + R_o$ (compression members)

$(1.5)S = D + F + L + H + T_o + R_o + W$ (tension members)

$(1.3)S = D + F + L + H + T_o + R_o + W$ (compression members)

Service Loading Combinations for Plastic Design

If plastic design methods are used, SC-I steel structures are designed for the following service loading combinations:

$Y = 1.7D + 1.7F + 1.7L + 1.7H$

$Y = 1.7D + 1.7F + 1.7L + 1.7H + 1.7W$

If stresses due to T_o and/or R_o are present on the structure, the following loading combinations are also considered:

$Y = 1.3D + 1.3F + 1.3L + 1.3\,H + 1.3T_o + 1.3R_o$

$Y = 1.3D + 1.3F + 1.3L + 1.3\,H + 1.3T_o + 1.3R_o + 1.3W$

Extreme Loading Combinations for SC-I Steel Structures

Extreme loading combinations for SC-I steel structures encompass the same type loads as included for extreme loading combinations for SC-I concrete structures in Section 11.1.7.4.2.1.

Extreme Loading Combinations for Elastic Working Stress Design

If elastic working stress design methods are used, SC-I steel structures are designed for the following extreme loading combinations:

$(1.6)S = D + F + L + H + T_o + R_o + E'$ (tension members)

$(1.4)S = D + F + L + H + T_o + R_o + E'$ (compression members)

$(1.6)S = D + F + L + H + T_o + R_o + W_t$ (tension members) (see note below)

$(1.4)S = D + F + L + H + T_o + R_o + W_t$ (compression members) (see note below)

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LIST OF ACRONYMS AND ABBREVIATIONS (continued)

EC	effluent concentration
ECR	Engineering Change Request
EDMS	Electronic Data Management System
EDST	Eastern Daylight Savings Time
EIS	Environmental Impact Statement
EMMH	external man-made hazard
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration
ERPG	Emergency Response Planning Guidelines
ES&H	Environment, Safety, and Health
ETF	Effluent Treatment Facility
FA	flame acceleration
FEM	finite element model
FEMA	failure modes and effect analysis
FHA	Fire Hazard Analysis
FIC	final isotopic composition
FM	Factory Mutual
FOCI	foreign ownership, control, or influence
fpm	feet per minute
ft	foot
g	gram
g	acceleration due to gravity
gal	gallon
gpm	gallons per minute
GSA	General Separations Area
GSAR	Generic Safety Analysis Report
GSG	geological, seismological, geotechnical
ha	hectare
HAN	hydroxylamine nitrate
HAZOP	hazards and operability study
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
HEPA	high-efficiency particulate air
HFE	human factors engineering
HIS	Human-system interface
HLW	high-level waste
HP	Health Physics
HPLC	high performance liquid chromatography
hr	hour
HVAC	heating, ventilation, and air conditioning
Hz	hertz
I&C	instrumentation and control
I/O	input/output

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

IAEA	International Atomic Energy Agency
ICBO	International Conference of Building Officials
ICP-MS	inductive coupled plasma – mass spectroscopy
ID	identification
IDLH	Immediately Dangerous to Life and Health
IEEE	Institute of Electrical and Electronic Engineers
IOC	Individual Outside the MFFF Controlled Area
in	inch
INES	International Nuclear Event Scale
IROFS	items relied on for safety
ISA	Integrated Safety Analysis
IT/SF	Interim Treatment/Storage Facility
ITP	In-Tank Precipitation Facility
ka	kilo annum or thousands of years
kg	kilogram
kip	kilopound
km	kilometer
kV	kilovolt
L	liter
lb	pound
LDE	Lens of the Eye Dose Equivalent
LETF	Liquid Effluent Treatment Facility
LFL	lower flammable limit
LLC	Limited Liability Company
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LOC	level of severity or concern
LPF	leak path factor
LWR	light water reactor
m	meter
M	molar
M&O	Maintenance and Operations
m^3	cubic meter
Ma	mega annum or millions of years
MACCS2	MELCOR Accident Consequence Code System for the Calculation of the Health and Economic Consequences of Accidental Atmospheric Radiological Releases
MAR	material at risk
mb	body wave magnitude
mbar	millibar
MBP	monobutyl phosphate
MC&A	Material Control and Accounting
MCC	motor control center
MCNP	Monte Carlo N-Particle
MD	duration magnitude

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11.3 AQUEOUS POLISHING PROCESS DESCRIPTION

This section provides a description and overview of the Aqueous Polishing (AP) Process, including design, operational, and process flow information. This information is provided to support the hazard and accident analysis provided in Chapter 5, as well as to assist in understanding the overall design and function of the AP Process.

11.3.1 Function

The function of the AP process is to remove impurities from the feed plutonium of the Pit Disassembly and Conversion Facility (PDCF) and of the Alternate Feedstock (AFS) for use in the MOX Processing (MP) Area. The AP process extracts impurities, predominantly gallium and americium, from the plutonium dioxide. The safety function of the principal SSCs associated with the AP process is discussed in Chapter 5.

11.3.2 Description

The AP process consists of 16 process units or systems (units symbols are indicated in parentheses):

- Decanning Unit (KDA)
- Milling Unit (KDM)
- Recanning Unit (KDR)
- Dissolution Unit (KDB)
- Dechlorination and Dissolution Unit (KDD)
- Purification Cycle (KPA)
- Solvent Recovery Cycle (KPB)
- Oxalic Precipitation and Oxidation Unit (KCA)
- Homogenization Unit (KCB)
- Canning Unit (KCC)
- Oxalic Mother Liquor Recovery Unit (KCD)
- Acid Recovery Unit (KPC)
- Offgas Treatment Unit (KWG)
- Liquid Waste Reception Unit (KWD)
- Waste Organic Solvent (KWS)
- Automatic Sampling System (KPG).

Figure 11.3-1 provides an overview of the AP process, and Figure 11.3-2 shows the AP general process diagram. In general, the AP process involves three major steps:

- **Dissolution of PuO_2 powder by electro-generated Ag (II)** – The dissolution step involves silver-catalyzed dissolution and filtration. This process was selected because it is very efficient and independent of PuO_2 powder characteristics. It results in the complete dissolution of the PuO_2 powder according to kinetics governed solely by the rate of Ag (II) generation. PuO_2 powder is dissolved by electro-generated Ag (II) in a nitric acid medium. This process takes place at normal temperature (68°F to 104°F [20°C to 40°C]). For PuO_2 powder containing chlorides, a dechlorination step takes place prior to dissolution

- **Plutonium purification by solvent extraction** – The purification step involves plutonium extraction, solvent regeneration, and acid recovery. This process was selected because it yields very little plutonium leakage and has a high gallium decontamination factor.
- **Conversion into PuO_2 by continuous oxalate calcination** – The conversion process is a continuous oxalate conversion process. This process was selected because it yields a PuO_2 powder routinely used for MOX fabrication. Conversion to PuO_2 involves several operations: oxalic precipitation and oxidation (which includes precipitation, filtration, and drying and calcination), PuO_2 homogenization, PuO_2 canning, and oxalic mother liquor recovery.

The following sections discuss the 16 AP process units or systems.

11.3.2.1 Decanning Unit (KDA)

11.3.2.1.1 Function

Three main functions are performed in the Decanning Unit:

- Density measurement by X ray (for PDCF powder only)
- Opening of outer, inner and convenience cans
- Transfer of powder in a dissolution dosing hopper (powder from PDCF) or in a reusable can to the Milling Unit (powder from AFS).

11.3.2.1.2 Description

The Decanning Unit consists of a series of workstations and gloveboxes distributed between the MP and AP Areas. The cans are transported between the two areas by a pneumatic transfer system.

- Density measurement by X Ray (for PDCF powder only)

  The purpose of this operation is to determine the bulk density of powder from PDCF which is a homogeneous powder. The whole sealed 3013 container is tilted to increase powder density in order to measure tap density. The level of powder in the can is measured by X-rays. From the measured powder mass and volume, the density is calculated. If this value is well below 7 g/cc then the can will be processed by the dissolver, whereas if this value is near 7 g/cc, the can will be processed similarly to AFS powder (i.e., ball milled and density measurement performed on powder) the nitric acid off-gas system treatment unit. Effluent solutions are stored in chlorine waste tanks prior to transfer to the SRS site.

11.3.2.5.4 Process Equipment

Figure 11.3-8 provides a simplified drawing of the Dechlorination and Dissolution Unit.

11.3.2.5.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved with the AFS powder and the PDCF feed powder in this unit are provided in Tables 11.3-6 and 11.3-7, respectively.

11.3.2.5.6 Chemical Process Ranges

The Dechlorination and Dissolution Unit is operated in batches. The operating ranges for both dissolution units are detailed in Section 11.3.2.4.6. The nominal flow rate to the Purification Cycle is approximately 3.8 gal/hr (14.4 L/hr).

The unit is sized to treat approximately 335 lbs (152 kg) of desorbed chlorine, Cl_2, per year.

11.3.2.5.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.5.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.6 Purification Cycle (KPA)

11.3.2.6.1 Function

The main goal of the Purification Cycle is to separate plutonium from impurities contained in the flux coming out of the Dissolution Units. The main functions of the Purification Cycle are as follows:

- Receive plutonium nitrate from the Dissolution Unit and the Dechlorination and Dissolution Unit
- Receive recycled plutonium nitrate from the Oxalic Mother Liquors Recovery Unit
- Receive solutions with high plutonium content from the laboratories
- Perform plutonium extraction and impurities scrubbing
- Perform plutonium stripping and uranium scrubbing
- Perform further plutonium purification by additional plutonium stripping and diluent washing
- Adjust plutonium to the tetravalent state
- Perform plutonium stripping in plutonium barrier

- Perform scrub bed uranium stripping and diluent washing
- Control purified plutonium and transfer to the Oxalic Precipitation and Oxidation Unit or recycle to the beginning of the Purification Cycle
- Control and dilute scrubbed uranium and prepare uranium for transfer to the Liquid Waste Reception Unit
- Wash, control, and transfer raffinates to the Acid Recovery Unit
- Wash, control, and transfer solvent/diluent to the Solvent Recovery Cycle
- Destroy residual HAN/hydrazine and hydrazoic acid in the aqueous phase transferred to the Oxalic Precipitation and Oxidation Unit.

11.3.2.6.2 Description

The Purification Cycle is designed to treat plutonium nitrate at a nominal flow rate of 4 gal/hr (15.1 L/hr), which corresponds to 32.0 lb/day (14.5 kg/day) of plutonium. Plutonium nitrate from the Dissolution Units is received, and plutonium is extracted and scrubbed for impurities. The plutonium is then separated from the uranium by stripping via adjustment of the plutonium valence to the trivalent state. The Purification Cycle controls plutonium reception, recycle, and transfer to the Oxalic Precipitation and Oxidation Unit. The Purification Cycle also controls the solvent and diluent streams to the Solvent Recovery Cycle and the raffinate stream to the Acid Recovery Unit.

The extraction process is continuous, but the feed solutions from the Dissolution Units are received in batches. The raffinate and the plutonium nitrate solutions are transferred periodically to the Acid Recovery Unit inlet buffer storage and to the Oxalic Precipitation and Oxidation Unit inlet buffer storage, respectively. The unloaded solvent is continuously transferred to the Solvent Recovery Unit and the stripped uranium solutions are directed to the liquid waste reception unit in batches.

Plutonium nitrate solution is batched to the feed tank TK1000 for plutonium extraction and impurities scrubbing. Pu (IV) in the aqueous solution (4.5N HNO_3) is extracted by the solvent (30% tributyl phosphate [TBP] in hydrogenated propylene tetramer [HPT]) in pulsed extraction column PULS2000. The impurities remain primarily in the aqueous phase. The solvent stream is scrubbed by 1.5N nitric acid in pulsed scrubbing column PULS2200 to ensure good decontamination. This acid contains aluminum nitrate to ensure fluoride decontamination. The aqueous raffinates are washed by the diluent in pulsed column PULS2100 and transferred to raffinate reception tank TK9000 after complexation of fluorides by a zirconium nitrate solution.

Extracted Pu (IV) is reduced to Pu (III) by hydroxylamine nitrate (0.46M HAN), and Pu (III) is stripped with a slightly acidic solution (0.1N HNO_3) containing hydrazine in pulsed stripping column PULS3000.

The remaining uranium present in the stripped plutonium aqueous phase is separated from the plutonium by solvent extraction in pulsed column PULS3200. A bypass of column PULS3200 is containing two stages of HEPA filters), and an exhauster before being released through the stack. Details of the final filtration units are found in Section 11.4.9.

11.3.2.13.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.13.4 Process Equipment

Figure 11.3-23 provides a simplified drawing of the Offgas Treatment Unit.

11.3.2.13.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-25 and 11.3-26, respectively.

11.3.2.13.6 Chemical Process Ranges

The Offgas Treatment Unit operates continuously. The NO_x scrubbing column is designed to treat approximately 62N m^3/h, including additional air. The designed capacity of the column pulsation air extraction is 150N m^3/h. The main ventilation line (offgas scrubbing and filters) is designed to process approximately 600N m^3/h, including additional air. The main flows of this unit are provided in Table 11.3-27.

11.3.2.13.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.13.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.14 Liquid Waste Reception Unit (KWD)

The Liquid Waste Reception Unit receives liquid waste from the AP process for temporary storage and pre-treatment before sending it offsite to SRS or the WSB for final treatment and disposal.

11.3.2.14.1 Function

The Liquid Waste Reception unit is dedicated to the reception, storage, and pre-treatment of the low level, high alpha, stripped uranium and organic waste streams.

- The low level liquid waste stream is comprised of the following: (1) room HVAC condensate, rinsing water from laboratories, and washing water from sanitaries which are potentially non-contaminated and are collected as low –low level liquid waste; (2) the distillate stream from the acid recovery unit which is contaminated and slightly acidic; and (3) miscellaneous floor washes from C2/C3 rooms and overflows or drip tray material from some of the reagent tanks in the AP building.

- The high alpha waste is a combination of three waste streams: americium, alkaline waste and excess acid. The americium stream collects americium and gallium nitrates and all of the silver used in the dissolution unit, along with traces of plutonium. The alkaline waste stream from the solvent recovery unit contains dilute caustic soda, sodium carbonate, sodium azide, and traces of plutonium and uranium. The excess acid stream from the acid recovery unit contains high alpha activity excess acid.

- The stripped uranium (< 1% U-235) waste stream receives the contents of the uranium dilution tanks in the purification cycle.

- The excess solvent/organic liquid waste stream receives the organic waste constitutes from the solvent recovery unit.

11.3.2.14.2 Description

Low Level Liquid Waste

Chemical waste tank #1, TK2050, collects overflows/drip tray contents from the de-mineralized water, nitric acid, manganese nitrate, and decontamination solution systems in a common header. It also collects overflows/drip tray contents from the sodium hydroxide and sodium carbonate systems in a separate common header. The tank is equipped with 1.5 N nitric acid and 0.1N sodium hydroxide addition systems for pH adjustment, a cooling loop to provide a means to remove the heat of reaction from acid/alkali reaction, a mixer, MIX2050, to provide agitation to aid mixing in the tank, and a manual sampling point. After pH adjustment, the low level waste is pumped to tank TK1000/TK2000.

Floor wash waste tank TK2060 collects the floor washes from all the uncontaminated C2 and C3 rooms in the AP area. These streams are generated in the course of routine housekeeping activities in these rooms and are separate from the overflows/drip tray streams that are collected in tank TK2050. The tank is equipped with a manual sampling point. The low level waste is periodically pumped to tank TK1000/TK2000.

Chemical waste tank #2, TK2070, is dedicated to oxalic acid service. It collects oxalic acid overflows/drip tray contents. The tank is equipped with a manual sampling point. The low level waste is pumped to portable drums for off-site disposal. The vents from these three tanks are collected in a vent header and routed to a nitric acid system scrubbing column.

Low level waste buffer tanks TK1000 and TK2000 collect the low, low level waste from room HVAC condensate, rinsing water from laboratories, washing water from sanitaries, and the contents of tank TK2060. These tanks also collect the distillate from the acid recovery unit, seal water from the vacuum radiation monitoring system, and the chemical wastes from tank TK2050. Tanks TK1000 and TK2000 operate in parallel. Three way valves are used to direct the flow to one of the two tanks. These tanks serve as buffer tanks and transfer the material to reception tank TK3000 for pH adjustment and sampling. A set of redundant pumps are used for the transfer. Piping and valves around the tanks and pumps allow the tank contents to be re-circulated to the tanks for mixing or to spray nozzles to wash down the tanks from the inside. Mixing is provided using the recirculation stream with an eductor.

11.3.2.15 Waste Organic Solvent Unit (KWS)

11.3.2.15.1 Function

The function of the Waste Organic Solvent Unit (KWS) is to handle the organic solvent generated in the AP Process and transfer it to SRS for handling and disposal.

11.3.2.15.2 Description

This unit consists of an intermediate solvent tank, a final solvent tank and a carboy filing station. It is designed to collect waste solvent for sampling to assure compliance with the SRS waste acceptance criteria (WAC).

The intermediate solvent tanks will receive waste solvents from solvent flush or drain lines from KPA, KPB, KPC, KWD, LGF and RDO to determine if they meet SRS requirements. This tank will be located in a closed process cell and will have mixing and automatic sampling capabilities. Solvent waste found to contain excess plutonium will be returned to KPA for reprocessing. Excess water (aqueous phase) found in the solvent wastes will be separated via a small collecting protrusion at the bottom of the tank and return to KWD. If the solvent waste meets the WAC, it will be transferred to final waste solvent tank.

The final waste solvent tank will receive solvent from the intermediate solvent tank and from the KPB solvent tank. This tank will be located in an open process cell and will have mixing and manual sampling capabilities. From this tank the waste solvent will be transferred to a carboy located in the solvent building. Each carboy will be loaded onto a truck via monorail for final disposition.

11.3.2.15.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.15.4 Process Equipment

Process Equipment will be provided in the ISA.

11.3.2.15.5 Chemical Process Inventories

This section is not applicable to this unit.

11.3.2.15.6 Chemical Process Ranges

Specific process ranges will be provided in the ISA.

11.3.2.15.7 Chemical Process Limits

Normal operating parameters and specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.16 Automatic Sampling System

This section describes the principles of liquid sampling and basic equipment design for the AP process. The sampling system is applicable for radioactive and chemical solutions. Three liquid sampling system principles that will be used at the MFFF are direct filling, suction filling, and remote sampling.

In direct sampling, the solution is directly extracted from the process equipment by gravity flow or with a recycling pump into a vial. Direct sampling is limited to non-aggressive reagents. A large sample volume provides a lower detection limit.

In suction sampling, a vial is filled by suction through a needle by the vacuum created in a vial prior to sampling. Suction filling can be performed manually or with a moving cask. Aggressive reagents can be sampled manually but with vacuum vial filling. A moving cask is used for suction filling of active liquids. Suction filling is used for sampling of inactive but aggressive liquid and for dubious liquid in cell drip-trays. This method is not used for high activity solution like concentrated liquid waste.

With remote sampling, the solution is lifted up by an airlift (or a pump) head from which direct vacuum sampling is carried out. All the air-lift (or the pump) heads are confined in a sampling box (three boxes at MFFF) where a manipulator is installed. The manipulator handles an empty vacuum vial, sets the vial into the proper needle position, and places the filled vial at a rinsing station prior to its pneumatic transfer to the Laboratory.

For concentrated radioactive liquid waste, remote sampling under a box is required. Table 11.3-34 summarizes the sampling systems. All sampling systems will be qualified using engineering studies and/or evaluations.

11.3.3 Major Components

The major components of each unit or system are described in Section 11.3.2.

11.3.4 Control Concepts

The control concepts used in the AP process are based on existing control principles of COGEMA'S URP and Plutonium Finishing Facility at La Hague in France. The AP process control systems are designed to ensure that the product of the manufacturing process will conform to the product specifications with minimal waste and risk. The AP process controls are composed of the normal, protective, and safety control subsystems. The normal control subsystem controls the MFFF normal manufacturing and processing operations. The protective control subsystem provides protection for personnel and equipment. The safety control subsystem is designed to ensure that safety limits will not be exceeded. Section 11.6 discusses the MFFF I&C systems in more detail.

In general, each unit is controlled by one or several programmable logic controllers (PLCs) associated with a monitoring workstation located in the AP control room. All units are operated in an automatic mode. The operator may also intercede via a manual mode in which the interlocks are active in case of trouble in the automatic mode or for maintenance operations.

The Manufacturing Management Information System (MMIS) collects the information coming from all process units to control the position and the exchange of special nuclear material (SNM) as well as the traceability and the quality of the products.

11.3.5 System Interfaces

The system interfaces of each unit or system are described in Section 11.3.2.

11.3.6 Design Basis for Non-Principal SSCs

- The design of the AP process is as similar as practical to the proven design currently employed at La Hague's Plutonium Finishing Facilities. Departures from the La Hague design result from United States regulatory requirements, lessons learned at La Hague, or manufacturing and throughput requirements specific to the MFFF.

Table 11.3-31. Inventory of Radionuclides for the Uranium Oxude Dissolution Unit

Table Deleted.

Table 11.3-32. Inventory of Chemicals for the Uranium Oxide Dissolution Unit

Table Deleted.

Table 11.3.33. Process Flows – Uranium Oxide Dissolution Unit

Table Deleted.

Table 11.3-34. Sampling System Classification

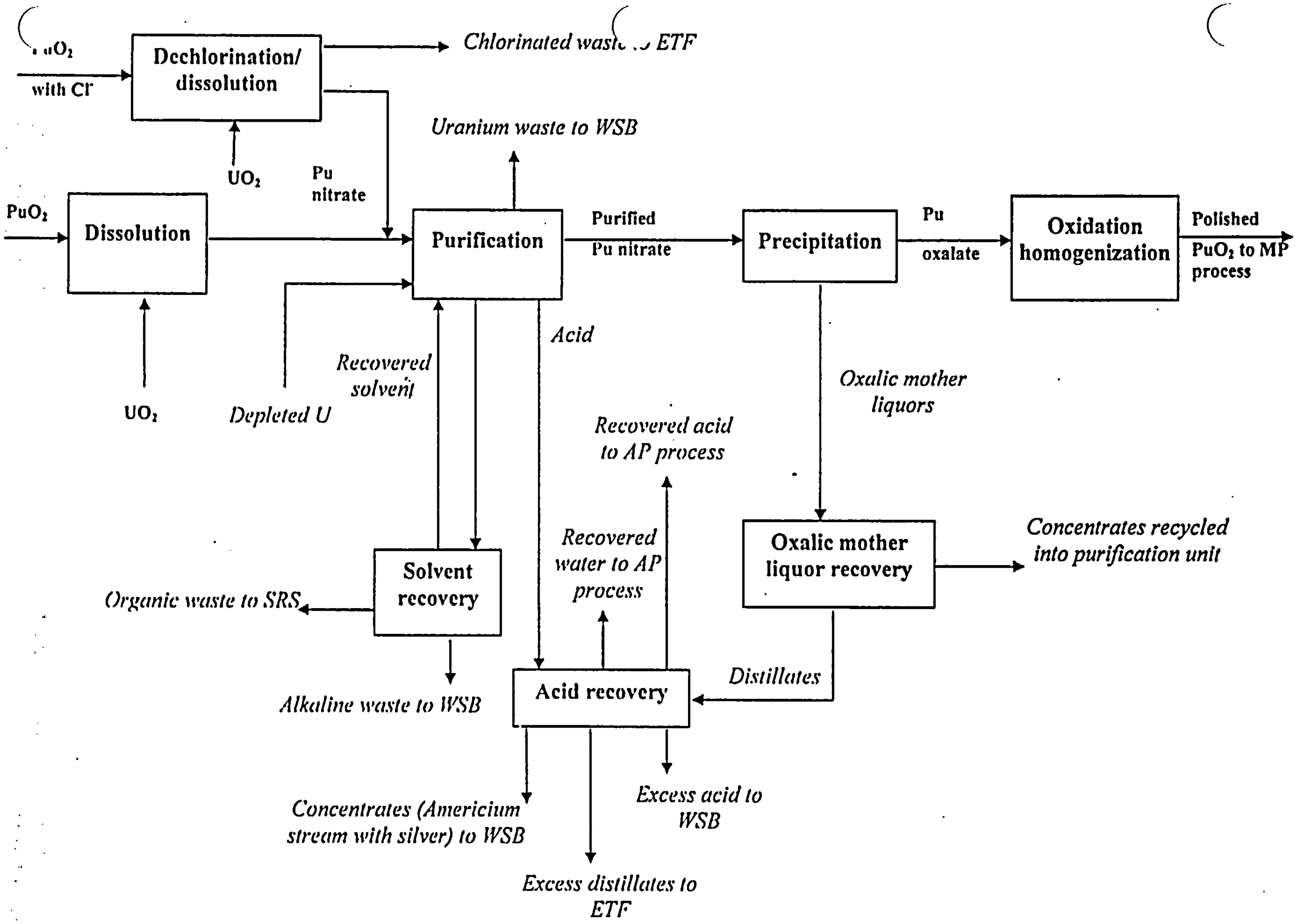

Figure 11.3-1. AP Process Overview

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Figure 11.3-2. General Flow Diagram

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Figure 11.3-6. Schematic of the Dissolution Unit

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Figure 11.3-8. Schematic of the Dechlorination and Dissolution Unit

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11.4 HVAC SYSTEMS AND CONFINEMENT

The MFFF HVAC systems and confinement principles are discussed in this section. The MFFF HVAC systems are designed to maintain radioactive material within process units and process enclosures, preventing the dispersal of radioactive material. In addition, these systems maintain required design temperatures during normal operations and design basis events.

Confinement of radioactive material is provided by the use of static barriers, generally in conjunction with dynamic systems. Gloveboxes and process enclosures provide static confinement barriers while the HVAC systems provide dynamic confinement. The static and dynamic systems are closely integrated to provide multiple layers of protection against the release of radioactive material.

The safety functions of the principal SSCs associated with these systems are discussed in Chapter 5. The design of the HVAC systems and confinement for the MFFF is consistent with the criteria and design guidance provided in Regulatory Guide 3.12, *General Design Guide for the Ventilation System of Plutonium Processing and Fuel Preparation Plants.* One noted exception to this Regulatory Guide is that there are no adsorbers in the filter lines therefore the heaters and water mist spray for fire protection of final HEPA filters are not required.

The following subjects are discussed in this section:

- Confinement principles
- MOX Fuel Fabrication Building HVAC systems
- Emergency Generator Building HVAC systems
- Standby Generator Building HVAC systems
- Safe Haven HVAC systems
- Reagent Processing Building HVAC systems
- Static barriers
- Fire protection and confinement
- Final filtration units and analysis
- Design basis for non-principal SSCs
- Design basis for principal SSCs.

11.4.1 Confinement Principles

This section provides a general description of the confinement principles used in the MOX Fuel Fabrication Building.

11.4.1.1 Function

The function of MFFF confinement and related systems is to control and prevent the dispersal of radioactive material.

11.4.1.2 Description

Confinement of radioactive material is provided by dividing the MOX Fuel Fabrication Building into multiple zones, with each zone based on different potentials for contamination. Confinement of radioactive material is provided by combining various static confinement barriers (e.g., vessels, gloveboxes, fuel rod cladding, and process rooms with dynamic confinement through the corresponding HVAC system). Static barriers effectively preclude leakage out of a confinement boundary. The associated dynamic confinement maintains a negative pressure with respect to the adjacent areas such that leakage air flows from zones of the lowest contamination risk to zones of increasing contamination risk. In those cases in which dynamic confinement is not utilized in conjunction with static confinement, confinement barriers are provided by sealed systems (e.g., 3013 containers and fuel rods). Confinement is the principal protection against the dispersal of radioactive material.

The MOX Fuel Fabrication Building uses three confinement levels to provide confinement of nuclear material: primary, secondary, and tertiary confinement. Each confinement level consists of static barriers and dynamic HVAC systems. The multiple levels of confinement are the basis for the division of the MOX Fuel Fabrication Building into confinement zones (i.e., C1, C2, C3, and C4 or process cells). Pressure gradients between zones ensure that leakage air flows from the zones of lowest contamination risk to zones of increasing contamination risk. For example, the contamination risk in C3 zones is higher than in C2 zones. Figures 11.4-1 and 11.4-2 provide graphical representations of the confinement philosophy for the MP and AP Areas, respectively.

Primary confinement mainly consists of process equipment, gloveboxes, and vessels containing radioactive material, rods, and 3013 canisters. The interior of these enclosures is classified as a C4 zone. Primary confinement SSCs are installed immediately around the radioactive material (see Table 11.4-1) and are intended to prevent dispersal of nuclear material into working areas and the environment. This design allows personnel to move and perform tasks without wearing respiratory protection. Primary confinement includes at least one static confinement barrier. In most cases, primary confinement also includes a corresponding HVAC system (normally the Very High Depressurization Exhaust System) with the exception being welded equipment.

Secondary confinement consists of process rooms, which are designated C3 zones and C2 zones. Secondary confinement SSCs (see Table 11.4-1) provide defense in depth to primary confinement. They provide additional assurance in protecting the environment and the IOC against an uncontrolled release of radioactive material. Secondary confinement includes static barriers (e.g., walls, floors, and roofs surrounding gloveboxes and process cells), waste drum storage, and the associated HVAC system (normally the High Depressurization Exhaust System).

In the case of welded SSCs (e.g., fuel rods, fuel assemblies, 3013 containers, and process vessels), secondary confinement is not necessary since primary confinement is provided by a sealed and welded barrier. In the case of the fuel rods, the sintered pellets are inserted into the cladding and the seal is welded. Furthermore, the fuel rods and assemblies are the "normal" forms of radioactive material transported to reactor facilities for use. In the case of plutonium oxide, the powder is received in DOE Standard 3013 containers, which consist of a convenience can, a welded inner can, and a welded outer can. The 3013 container provides primary and secondary confinement of the nuclear material.

Tertiary confinement SSCs consist of rooms designated as C2 zones and the Process Cells. Tertiary confinement (see Table 11.4-1) includes static barriers (e.g., the walls, floors, and roofs surrounding the remaining portions of the MP and AP Areas) and their associated HVAC systems (normally the Medium Depressurization Exhaust System for C2 zones and the process cell exhaust system for process cells). Tertiary confinement static barriers provide defense in depth to primary and secondary confinement by minimizing dispersal of radioactive material. Tertiary dynamic confinement provides an additional protection feature for protecting the environment and IOC.

11.4.1.2.1 Confinement Zones

The MFFF equipment and facility boundaries provide static barriers and are classified into the following confinement zones as shown in Figures 11.4-3 through 11.4-10:

- Process vessels and equipment containing radioactive materials (includes fuel rods and 3013 containers)
- C4 zones, where contamination is inherent to the process (e.g., gloveboxes)
- C3 zones, further subdivided into two subzones:
  - C3b, where contamination risk is moderate (e.g., process rooms containing gloveboxes)
  - C3a, where contamination risk is low (e.g., airlocks to process rooms, rooms containing C3b exhaust HVAC filters)
- Process cells, where the likelihood of contamination is very low (e.g., process rooms containing process vessels)
- C2 zones, where contamination risk is very low (e.g., process rooms containing rods or assemblies, corridors around C3 areas)
- C1 zones, where contamination risk is virtually zero (e.g., areas with an opening to the outside).

11.4.1.2.2 Dynamic Systems

The HVAC systems work with the static confinement barriers by maintaining a negative pressure gradient from the zones of lowest risk toward the zones of increasing risk. The HVAC systems also ensure suitable air filtration prior to atmospheric release.

In the AP and MP Areas, dynamic confinement of C4 confinement enclosures is ensured by the Very High Depressurization Exhaust System. In the AP Area, dynamic confinement of process cells within tertiary confinement is provided by the Process Cell Exhaust System. In the AP and MP Areas, dynamic confinement of C3a and C3b rooms within secondary confinement is provided by the High Depressurization Exhaust System. In the AP and MP Areas, dynamic confinement of C2 rooms within tertiary confinement is provided by the Medium Depressurization Exhaust System. For the AP process cells, the typical cascading sequence of pressure gradients between neighboring zones is as follows:

C1 → C2 → process cells → process vessel

For the AP and MP Areas with gloveboxes containing dispersible material, the typical sequence is as follows:

C1 → C2 → C3a → C3b → C4

In both examples, leakage airflow is from high pressure to low pressure.

11.4.1.2.3 Confinement Zone Interfaces

Static confinement barriers include supplemental provisions around openings (e.g., personnel or equipment access, HVAC ducts) to reduce the risk of contamination leaks. The major interfaces and their supplemental confinement features are as follows:

- **Airlocks** – Airlocks are used for personnel and equipment access from one confinement zone to another. The airlock consists of a minimum-leakage door and is ventilated by the highest adjacent confinement zone.
- **Penetrations for HVAC ducts** – Penetrations have at least one high-efficiency particulate air (HEPA) filter installed at each penetration between C4 and C3 zones or between C3 and C2 zones.
- **Equipment access to gloveboxes** – Equipment is moved into gloveboxes usually via a bag port or an airlock.

11.4.1.3 Major Components

MFFF confinement includes the following dynamic and static SSCs:

- Offgas Treatment Unit (Section 11.3)
- Very High Depressurization Exhaust System (Section 11.4.2.2)
- High Depressurization Exhaust System (Section 11.4.2.3)
- Process Cell Exhaust System (Section 11.4.2.4)
- Medium Depressurization Exhaust System (Section 11.4.2.5)
- Gloveboxes (Section 11.4.7.1)
- DOE Standard 3013 Canisters and Transport Casks (Section 11.4.7.2)
- Fuel rod cladding (Section 11.4.7.6)
- Process vessels, equipment, cells, and rooms (Section 11.3)
- Process equipment (e.g., sintering furnace, inflatable seal) (Section 11.2)
- MOX Fuel Fabrication Building (Section 11.1).

11.4.1.4 Control Concepts

Control concepts are discussed for each of the major components within their respective sections (listed above).

11.4.1.5 System Interfaces

In general, MFFF confinement systems and components (indicated above) interface with each other, with instrumentation and controls, and with normal, standby, and emergency power.

11.4.2 MOX Fuel Fabrication Building HVAC Systems

The MOX Fuel Fabrication Building HVAC systems are shown in Figures 11.4-11 and 11.4-12. The MOX Fuel Fabrication Building HVAC systems maintain differential pressures between confinement zones and maintain an environment suitable for personnel and process operations.

The MOX Fuel Fabrication Building HVAC systems discussed in this section are as follows:

- Offgas Treatment Unit
- Very High Depressurization Exhaust System
- High Depressurization Exhaust System
- Process Cell Exhaust System
- Medium Depressurization Exhaust System
- Supply Air System
- Emergency Control Room Air-Conditioning System
- Truck Bay Ventilation System
- Shipping and Receiving Area Air-Conditioning System.

11.4.2.1 Offgas Treatment Unit

The functions, description, major components, control concepts, and interfaces of the Offgas Treatment Unit are described in Section 11.3.1.13.

11.4.2.2 Very High Depressurization Exhaust System

11.4.2.2.1 Function

The functions of the Very High Depressurization (VHD) Exhaust System are as follows:

- Maintain a negative pressure differential between the C4 (glovebox) and C3 (process room) confinement zones
- Filter contaminants from glovebox exhaust gases/air prior to discharge through the exhaust stack
- Maintain an environment suitable for the manufacturing process.

See Chapter 5 for a list of safety functions.

11.4.2.2.2 Description

The VHD Exhaust System is depicted schematically on Figure 11.4-11. The VHD Exhaust System provides confinement of radioactive materials within the glovebox by maintaining a continuous negative differential pressure between the C4 and C3 confinement zones under normal operating conditions.

During a tornado, the HDE, MDE, POE and HSA systems are shut down during the period when the tornado dampers are closed. The VHD system continues to run against the closed tornado dampers. The HDE, MDE, POE and HSA systems are re-started after the tornado passes.

The glove box atmosphere is exhausted through two stages of HEPA filters at the glovebox boundary, one stage of HEPA filters at the C3 boundary, and two stages of final HEPA filters prior to being discharged to the atmosphere through the MFFF stack, which is continuously monitored. Air or gases supplied to the gloveboxes are supplied through two stages of HEPA filters. The filters on the supply and exhaust of each glovebox are provided to confine radioactive materials within the glovebox as close to the point of origin as practical.

At least one stage of the glove box inlet or exhaust HEPA filtration is testable. The filter design for the glove boxes includes one bag-out type filter housing on the inlet and exhaust with in place testing ports, on the filter housing, to check for proper seating of the filter. This filter housing is on the external stages only. The HEPA filter stage on the inside of the glove box are not tested. All intermediate HEPA filters at the C3 boundaries have the same provisions, as above, for testing. Exhaust flow is maintained by one of four 100%-capacity exhaust fans located downstream of two 100%-capacity final filtration units. The exhaust fans discharge to the MOX Fuel Fabrication Building stack.

The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air (and gas as applicable) through each glovebox. Fire-rated protective features are provided when ductwork passes through a fire barrier into another fire area.

Components of the Very High Depressurization Exhaust System can be tested periodically for operability and required functional performance. Airflow can periodically be measured in the exhaust ducts and at gloveboxes. The operating sequence that would bring the spare components into service and transfer to alternate power sources can be tested periodically.

The glovebox exhaust is conveyed through a common exhaust duct to the fans and final filters of the VHD Exhaust System. This exhaust path is used to maintain the environmental requirements of the equipment contained within the glovebox, remove heat, maintain the operating differential pressure, and provide the much higher exhaust flows from a glovebox, if a maximum postulated breach of confinement were to occur. The higher flow required by a breach of confinement is initiated by the opening of automatic dump valves that allow sufficient flow to assure that a minimum velocity of 125 ft/min (38.1 m/min) is achieved through the maximum postulated breach.

The VHD Exhaust System also exhausts the intermittent flows from the discharge of the pneumatic transfer fans in the NTP, LTP, and LLP systems.

11.4.2.2.3 Major Components

The VHD Exhaust System contains the following major components:

- Four 100%-capacity, variable-speed, centrifugal fans with direct-drive motors.
- Two 100%-capacity final filtration units. The filter trains are described in more detail in Section 11.4.9.1.
- Single-stage intermediate HEPA filters. Filters not located in gloveboxes are installed in stainless bag-in/bag-out housing with differential pressure indicators.

The ductwork upstream of the intermediate HEPA filters for the VHD Exhaust System is welded stainless steel pipe with flanged joints where the ductwork connects to equipment and in-line components. The ductwork downstream of the intermediate filters is welded stainless steel.

11.4.2.2.4 Control Concepts

The variable-speed exhaust fans maintain constant pressure at the inlet to the final filters with respect to atmosphere. The system is designed so that one fan is capable of meeting normal and abnormal flow requirements. The other fans are in standby. The standby fans automatically start upon a trip of the lead exhaust fan or the failure of the system to maintain adequate differential pressure at the inlet to the final HEPA filter units. Pressure-regulating valves at each glovebox maintain the required differential pressure in the glovebox at approximately -1.4 in WG to -2.0 in WG (-298 to -498 Pa). Over- and under-pressure protection is provided at the glovebox. The over- and under-pressure protection is set at approximately -0.8 in WG (-200 Pa) and -3.0 in WG (-746 Pa), respectively ("over-pressure" refers to insufficient depressurization).

The control circuits for the VHD Exhaust System are normally interlocked with the control circuits of the High Depressurization (HD) Exhaust System, the Medium Depressurization (MD) Exhaust System, and the Supply Air System to prevent operation of the ventilation systems unless a VHD Exhaust fan is operating and the system is maintaining adequate differential pressure at the inlet to the VHD final HEPA filter units. This design ensures that the pressure differentials in the gloveboxes and process rooms comprising the C4 and C3 confinement zones maintain a pressure gradient such that C4 zones are maintained more negative than C3 zones.

Differential pressure-indicating switches are provided for each final filter unit and pressure differential indicators are provided for each intermediate filter and glove box filter to provide pressure differential data to operations and maintenance personnel so that filters can be changed out at appropriate times in accordance with ASME AG-1 or following identified exposures to water or chemicals. Flow instrumentation is provided to monitor the system flow rates.

Temperature detectors are provided at the inlet of each final filtration unit to provide a temperature indication and alarm in the event of high temperature in the ductwork.

Nitrogen or dry air is supplied to a glovebox at a constant rate. Nitrogen or dry-air supply is automatically terminated at the over-pressure set point of the glovebox.

Pressure controls are provided to vary the operating fan speed to maintain a constant pressure differential in the glovebox, nominally -1.4 to -2.0 in WG (-298 to -498 Pa) with respect to the process room.

11.4.2.2.5 System Interfaces

Each of the four 100%-capacity exhaust fans is powered from the normal, standby, emergency, and uninterruptible power supplies. The VHD system interfaces with the HD Exhaust System, the MD Exhaust System, and the supply air system to control the differential pressure between the C3 (process room) and C4 (glovebox) confinement zones. The VHD Exhaust System also interfaces with the Nitrogen System, the Instrument Air System (dry air) for glove box ventilation and air operated valves. The pneumatic transfer system, sintering furnace off gas system and the precipitator-calcination unit exhaust discharge into the VHD exhaust duct. The radiation monitoring system (CAMs) sample the VHD exhaust at multiple points within the AP and MP buildings.

11.4.2.3 High Depressurization Exhaust System

11.4.2.3.1 Function

The functions of the HD Exhaust System are as follows:

- Maintain a negative pressure differential between the C3 (process room) confinement zone and the C2 confinement zone
- Ventilate the 3013 can storage area in the C2 confinement zone
- Ventilate the emergency power supply rooms serving the VHD Exhaust System fans, the HD Exhaust System fans, and the POE Exhaust system fans serving the process cells
- Filter contaminants from the exhausted air prior to discharge through the MOX Fuel Fabrication Building exhaust stack
- Maintain an environment suitable for operating personnel.

11.4.2.3.2 Description

The HD Exhaust System is depicted schematically on Figure 11.4-11. The HD Exhaust System provides confinement of radioactive materials within the process rooms by maintaining a continuous negative differential pressure between the C3 and C2 confinement zones. The rooms in the C3 confinement zone consist largely of process rooms containing gloveboxes.

The process room air is exhausted through one stage of HEPA filters as close to the C3 boundary as practical and two stages of final HEPA filters prior to being discharged to the atmosphere through the MFFF stack. Air is supplied to the process rooms through one stage of HEPA filters. The filters on the supply and exhaust of the process rooms are provided to confine radioactive materials within the process room as close to the point of origin as practicable.

Exhaust flow is maintained by one of two 100%-capacity exhaust fans located downstream of two 100%-capacity final filtration units. The exhaust fans discharge to the MOX Fuel Fabrication Building exhaust stack.

All HEPA filters at the C3 boundaries have in place testing ports, on the filter housing, to check for proper seating of the filter.

The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air through each room. Fire-rated protective features are provided when ductwork passes through a fire barrier into another fire area.

Components of the HD Exhaust System can be tested periodically for operability and required functional performance. Airflow can periodically be measured in the exhaust ducts and at gloveboxes. The operating sequence that would bring the spare components into service and transfer to alternate power sources can be tested periodically.

The system provides sufficient exhaust air, when operated with the emergency air supply of the Supply Air System, to maintain the temperature in the 3013 can storage areas and the emergency power supply rooms at or below the maximum design temperature.

Air is supplied uniformly, as high in the room as practicable, to provide a low velocity flow over the glovebox. The air is exhausted near the floor through grilles or registers. This flow pattern sweeps contaminants from the areas surrounding the operator's access points, minimizing possible contamination.

Battery rooms served by this system are ventilated to prevent the build up of explosive levels of hydrogen. The ventilation rate is a minimum of two air changes per hour in accordance with NFPA -111 and limit hydrogen accumulation to less than 2% of the room volume in accordance with IEEE 484. A standby exhaust fan is provided for all battery rooms.

The ventilation system and gloveboxes ensure that the airborne concentration in occupied operation areas remains well below the limits of 10 CFR Part 20. Continuous air monitors (CAMs) are placed in radiation areas to monitor potential airborne radioactive contaminants and to warn workers by alarming in the event of unsafe conditions. Personnel located at workstations where there is an increased inhalation risk are continuously monitored with mobile CAM heads, as appropriate, while coverage of general workplaces is provided by general area CAMs. Chapter 9 provides more details concerning the radiation protection program.

11.4.2.3.3 Major Components

The HD Exhaust System contains the following major components:

- Two 100%-capacity, variable-speed, centrifugal fans with direct-drive motors.
- Two 100%-capacity final filtration units. The filter trains are described in more detail in Section 11.4.9.1.
- Single-stage intermediate HEPA filters. Filters are located in stainless bag-in/bag-out housing with differential pressure indicators.

The ductwork upstream of the final HEPA filter units is welded stainless steel with flanged joints where the ductwork connects to equipment and in-line components. Ductwork downstream of the final HEPA filter units is welded galvanized steel.

11.4.2.3.4 Control Concepts

The variable-speed exhaust fans maintain constant pressure at the inlet to the final filters with respect to the atmosphere. The system is designed so that one fan is capable of meeting normal and abnormal flow requirements. The other fan is in standby. The standby fan automatically starts upon loss of negative pressure at the final filter housing

The control circuits for the HD Exhaust System are normally interlocked with the control circuits of the VHD Exhaust System, MD Exhaust System, and Supply Air System to prevent operation of the ventilation systems unless the VHD Exhaust System is operating. This design ensures that the C4, C3, and C2 confinement zones maintain a pressure gradient from the highest to lowest pressure such that the C4 zone is maintained more negative than the C3 confinement zone, which is maintained more negative than the C2 confinement zone.

Flow instrumentation is provided upstream of the final filters to monitor the system flow rates. Temperature detectors are provided in the ductwork upstream of each final filtration unit to provide an alarm in the event of high temperature in the ductwork. Pressure controls are provided to vary the operating fan speed to maintain a constant pressure differential in the process rooms, nominally -0.6 to -0.75 in WG (-124 to -180 Pa), with respect to the atmosphere.

11.4.2.3.5 System Interfaces

The HD exhaust fans are powered from the normal, standby, and emergency power supplies. The system interfaces with the VHD Exhaust System, the MD Exhaust System and the Supply Air System.

11.4.2.4 Process Cell Exhaust System

11.4.2.4.1 Function

The functions of the Process Cell Exhaust System are as follows:

- Maintain a negative pressure differential between the process cell confinement zone and the C2 confinement zone
- Filter contaminants from process cell exhaust air prior to discharge through the exhaust stack
- Maintain an environment suitable for the manufacturing process.

11.4.2.4.2 Description

The Process Cell Exhaust System is depicted schematically on Figure 11.4-11. The Process Cell Exhaust System provides confinement of radioactive materials within the process cell by maintaining a continuous negative differential pressure between the process cell and the C2 confinement zones.

The system exhausts air from the process cells in the AP Area, rooms that are not normally accessible and contain welded process equipment (all welded fittings). Air is supplied near the ceiling and removed near the floor (above the level of potential liquid spills).

Exhaust flow is maintained by one of two 100%-capacity exhaust fans located downstream of two 100%-capacity final filtration units. The exhaust fans discharge to the MOX Fuel Fabrication Building exhaust stack.

The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air through each cell. Fire-rated protective features are provided when ductwork passes through a fire barrier into another fire area.

Components of the Process Cell Exhaust System can be tested periodically for operability and required functional performance. Airflow can periodically be measured in the exhaust ducts. The operating sequence that would bring the spare components into service and transfer to alternate power sources can be tested periodically.

11.4.2.4.3 Major Components

The Process Cell Exhaust System contains the following major components:

- Two 100%-capacity, variable-speed, centrifugal fans with direct-drive motors.
- Two 100%-capacity final filtration units. The filter trains are described in more detail in Section 11.4.9.1.

The ductwork in the Process Cell Exhaust System upstream of the final HEPA filter units is welded stainless steel. The ductwork downstream of the final HEPA filter housings is welded galvanized steel.

11.4.2.4.4 Control Concepts

The variable-speed exhaust fans maintain constant pressure at the inlet to the final filters with respect to the atmosphere. The system is designed so that one fan is capable of meeting normal and abnormal flow requirements. The other fan is in standby. The standby fan automatically starts upon loss of negative pressure at the final filter housing.

The control circuits for the Process Cell Exhaust System are normally interlocked with the control circuits of the KWG Exhaust System to allow a permissive start. This design ensures that the Process Cells maintain a pressure more negative than the surrounding C2 confinement zone.

Flow instrumentation is provided upstream of the final filters to monitor the system flow rates. Temperature detectors are provided in the ductwork upstream of each final filtration unit to provide an alarm in the event of high temperature in the ductwork. Pressure controls are provided to vary the operating fan speed to maintain a constant pressure differential in the process cells, nominally -0.72 to -0.88 in WG (-180 to -220 Pa), with respect to the atmosphere.

11.4.2.4.5 System Interfaces

The process cell exhaust fans are powered from the normal, standby, and emergency power supplies. The system interfaces with the KWG Exhaust System. If KWG is running, an operator can manually start the POE fans.

11.4.2.5 Medium Depressurization Exhaust System

11.4.2.5.1 Function

The functions of the MD Exhaust System are as follows:

- Maintain a negative pressure differential between the C3 (process room) and C2 confinement zone
- Filter contaminants from the exhaust air prior to discharge through the exhaust stack
- Maintain an environment suitable for operating personnel
- Provide a common exhaust stack for discharge of process vents and ventilation exhaust.

11.4.2.5.2 Description

The MD Exhaust System is depicted schematically on Figure 11.4-11. The MD Exhaust System provides confinement of radioactive materials within the MOX Fuel Fabrication Building by maintaining a continuous negative differential pressure between the C2 and C1 (environment) confinement zones.

The system exhausts air from rooms in the MOX Fuel Fabrication Building designated as C2 confinement areas, except those rooms requiring cooling during emergency operation. The rooms in the C2 confinement zone consist largely of process unit control rooms, electrical rooms, and manufacturing process rooms for operations associated with the following: 3013 container receiving, unpacking, and nondestructive assay activities; rod storage and inspection; assembly mounting, inspection, and storage; and fuel cask loading.

Exhaust flow is maintained by one of two 100%-capacity exhaust fans located downstream of the final filtration units. Sufficient spare filtration units are provided to permit removal of one unit for service and testing while maintaining 100% flow capacity. The exhaust fans discharge to the MOX Fuel Fabrication Building exhaust stack.

The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air through each room. Fire-rated protective features are provided when ductwork passes through a fire barrier into another fire area.

Components of the MD Exhaust System can be tested periodically for operability and required functional performance. Airflow can periodically be measured in the exhaust ducts. The operating sequence that would bring the spare components into service and transfer to alternate power sources can be tested periodically.

Exhaust flows from the process vent systems and the VHD Exhaust System, HD Exhaust System, and Process Cell Exhaust System are combined and discharge through a common exhaust stack. The stack effluent is monitored. Chapter 10 describes the stack monitoring systems.

11.4.2.5.3 Major Components

The MD Exhaust System contains the following major components:

- Two 100%-capacity, variable-speed, centrifugal fans with direct-drive motors.
- Multiple final filtration units. The filter trains are described in more detail in Section 11.4.9.1.

The ductwork upstream of the final HEPA filter units is welded stainless steel with flanged joints where the ductwork connects to equipment and in-line components. The ductwork downstream of the final HEPA filter units is welded galvanized steel.

11.4.2.5.4 Control Concepts

The variable-speed exhaust fans maintain constant pressure at the inlet to the final filters with respect to the atmosphere. The system is designed so that one fan is capable of meeting normal flow requirements. The other fan is in standby. The standby fan automatically starts upon loss of negative pressure at the final filter housing.

The control circuits for the MD Exhaust System are normally interlocked with the control circuits of the VHD exhaust system, the HD Exhaust System and Supply Air System to prevent operation of the ventilation systems unless the VHD exhaust system and HD Exhaust System are operating. This design ensures that the pressure differentials in the process rooms and rooms comprising the C3, C2, and C1 confinement zones maintain a pressure gradient from the highest to lowest pressure such that the C3 confinement zone is more negative than the C2 confinement zone and the C2 confinement zone is more negative than the C1 confinement zone.

Flow instrumentation is provided upstream of the final filter to monitor the system flow rates. Temperature detectors are provided in the ductwork upstream of each final filtration unit to provide an alarm in the event of high temperature in the ductwork. Pressure controls are provided to vary the operating fan speed to maintain a constant pressure differential in the process rooms, nominally -0.2 to -0.4 in WG (-50 to -100 Pa), with respect to the atmosphere.

11.4.2.5.5 System Interfaces

The MD exhaust fans are powered from the normal and standby power supplies. The system interfaces with the HD Exhaust System and the Supply Air System.

11.4.2.6 Supply Air System

11.4.2.6.1 Function

The functions of the Supply Air System are as follows:

- Maintain a pressure differential between the C4 (gloveboxes), C3 (process rooms), process cells, and C2 (rooms) confinement zones
- Provide a source of unconditioned air for emergency cooling of the 3013 storage vault and emergency electrical rooms
- Maintain an environment suitable for operating personnel
- Maintain an environment suitable for the process, manufacturing, electrical, and laboratory equipment.

11.4.2.6.2 Description

The Supply Air System is depicted schematically on Figure 11.4-11. The Supply Air System supplies conditioned outside air to rooms and spaces designated as C2, process cell, and C3 confinement zones in the MOX Fuel Fabrication Building. The supply air fans draw air from the outside, through two sets of filters, heaters, and cooling coils, to condition the air for distribution in the MOX Fuel Fabrication Building. The supply air filter housing also contains freeze protection to permit continued operation of the emergency air supply in cold weather. Supply airflow is maintained by one of two 100%-capacity fans.

Rooms in C2 areas with high heat loads, principally electronics rooms, are provided with unit coolers to supplement cooling capability of the supply air. Additionally, duct-mounted cooling coils are provided where necessary to further cool the supply to meet ambient temperature criteria.

The ductwork incorporates manual and automatic dampers and controls to distribute and regulate the movement of air to each room. Fire-rated protective features are provided when ductwork passes through a fire barrier into another fire area.

Components of the Supply Air System can be tested periodically for operability and required functional performance. Airflow can be measured in the supply ducts. The operating sequence that would bring the spare components into service and transfer to alternate power sources can be tested periodically.

11.4.2.6.3 Major Components

The Supply Air System contains the following major components:

- Two 100%-capacity, variable-speed, centrifugal fans with direct-drive motors
- One set of multi-stage electric heating coils
- One set of multi-bank cooling coils and multiple supplemental cooling coils
- One prefilter bank (atmospheric dust filters)

- One HEPA filter bank
- Chilled water unit coolers.

The ductwork in the Air Supply System is galvanized steel.

11.4.2.6.4 Control Concepts

The variable-speed supply fans maintain constant flow to the MOX Fuel Fabrication Building. The system is designed so that one fan is capable of meeting normal and abnormal flow requirements. The other fan is in standby. The standby fan automatically starts upon loss of flow in the supply air duct.

The control circuits for the Supply Air System are normally interlocked with the control circuits of the VHD Exhaust System, Process Cell Exhaust System, HD Exhaust System, and the MD Exhaust System to prevent operation of the Supply Air System unless these systems are operating. This design ensures that the pressure differentials in the process cells and rooms comprising the C3, process cell, C2, and C1 confinement zones maintain a pressure gradient from the highest to lowest pressure such that the process cell is maintained more negative than the C3 confinement zone, the C3 confinement zone is maintained more negative than the C2 confinement zone, and the C2 confinement zone is maintained more negative than the C1 confinement zone.

Flow instrumentation is provided to monitor the system flow rates. Temperature detectors are provided in the ductwork to provide an alarm in the event of high temperature. Temperature controls are provided to heat or cool the supply air temperature as necessary. Room temperature controls are provided to control the temperature of rooms provided with supplemental unit coolers.

11.4.2.6.5 System Interfaces

The supply air fans are powered from the normal and standby power supplies. The electric heating coils are powered from the normal power supply. The system interfaces with the VHD Exhaust System, HD Exhaust System, and MD Exhaust System. The HVAC Chilled Water System supplies chilled water to the cooling coils.

11.4.2.7 Emergency Control Room Air-Conditioning System

11.4.2.7.1 Function

The functions of the Emergency Control Room Air-Conditioning System are as follows:

- Maintain a habitable environment in each of the two emergency control rooms for facility personnel
- Provide cooling to the emergency electrical rooms.

11.4.2.7.2 Description

The Emergency Control Room Air-Conditioning System is depicted schematically on Figure 11.4-12. The Emergency Control Room Air-Conditioning System maintains a habitable environment for facility personnel in each of the two emergency control rooms. The HVAC system is of sufficient capacity to maintain the rooms within acceptable temperature ranges and maintain a positive pressure of 0.125 in. WG. with respect to surrounding areas.

Fresh air inlets are located where it is most unlikely for contaminants to be present in order to reduce the possibility of contaminants being introduced into the control rooms as required by NFPA 801, Section 3-9.7.13.48. The fresh air inlets are furnished with tornado missile protection hoods.

The Emergency Control Room HVAC System is designed to operate at all times to maintain temperature, ventilation, and pressure control.

Each independent outside air intake is capable of supplying air to each of the emergency control rooms and is provided with gas-tight isolation capability. Outside air and recirculated inside air passes through the filtration units; each filter housing contains a hazardous gas removal cartridge and/or an organic vapor cartridge and HEPA filter cartridges, as determined by the ISA. The system also maintains appropriate temperature limits for human occupancy by recirculating air through heating and cooling elements. The system also provides cooling to maintain appropriate temperature limits for emergency electrical equipment. Each emergency control room intake is monitored for radiological and hazardous chemicals. Each emergency control room is equipped with breathing air outlets and sufficient quantities of self-contained breathing apparatuses.

Battery rooms, served by this system are ventilated to prevent the build up of explosive levels of hydrogen. The ventilation rate is a minimum of two air changes per hour in accordance with NFPA -111 and limit hydrogen accumulation to less than 2% of the room volume in accordance with IEEE 484. A standby exhaust fan is provided for all battery rooms.

11.4.2.7.3 Major Components

The Emergency Control Room Air-Conditioning System contains the following major components:

- Four 100%-capacity, self contained, air-conditioning units, one for each emergency control rooms and emergency electronics rooms for the A & B trains and one unit for the emergency electrical rooms and emergency battery rooms for the A & B trains. Each unit consists of a filter, a direct-expansion cooling coil with an associated refrigeration system, and condenser.
- Two 100%-capacity air filter trains, one for each emergency control room. Each unit consists of a filtration unit and a booster fan for each intake. The filter housings are stainless steel. Each filter housing contains a hazardous gas removal cartridge and/or an organic vapor cartridge and HEPA filter cartridges.
- Three, duct mounted, electric heaters for train A & B.

After power to the furnace is tripped, no safety systems are required to maintain primary confinement.

11.4.7.8 Vessels

Vessels provided in the AP systems that provide a primary confinement function are welded construction and are vented by the Offgas Treatment System. Vessels that may require access are located in gloveboxes, which provide primary confinement.

11.4.8 Fire Protection and Confinement

In the event of a fire, nuclear materials must be confined. Fire and nuclear material confinement barriers generally include a group of rooms, constituting a volume capable of containing the radioactive products that may be released by a fire within the area. Figure 11.4-14 provides an overview of the fire and nuclear material confinement barriers for process rooms.

The fire areas are surrounded by fire-rated barriers. Access to rooms is via a confinement airlock with a separate HVAC exhaust duct. Fire dampers capable of operating at high temperatures are placed on the room HVAC inlet and exhaust. Exhaust system components are designed with the proper temperature rating so that they can perform their required function under the conditions that may exist in the event of a fire. Air stream dilution is used to protect the final filter stage before the stack. The dilution factor depends on the temperature of the fire, the flow rate, and the flow of dilution air. Fire detection and suppression are described in Chapter 7.

For areas with no dispersible nuclear material, fire dampers are provided on the inlet and exhaust that are closed automatically upon sensing high temperature or upon activation of the gas suppression system.

For areas with dispersible nuclear material and without gloveboxes (e.g., waste storage and polishing cells), the main objective is to maintain differential pressure between the room and the surrounding areas. In case of fire, the fire damper on the HVAC inlet is automatically closed in order to limit air supply to the fire. The exhaust fire isolation damper is manually closed if set thresholds (e.g., temperature of exhaust, temperature at the last filtration level before the stack, pressure drop at the last filtration level and low flow rate at the stack) are exceeded.

For areas with gloveboxes, a change in the HVAC configuration could impair the pressure gradient between gloveboxes and the room. No modification in the HVAC configuration is expected in the case of an incipient fire that can be suppressed immediately. For the case of a larger fire, the main confinement principle is to maintain differential pressure between the room and the surrounding areas. The fire damper on the room HVAC inlet is automatically closed. The fire isolation valve on the glovebox HVAC inlet and exhaust are manually closed. The exhaust fire isolation damper (room) and/or fire isolation valve (glovebox) is manually closed if set thresholds (e.g., temperature on exhaust, temperature at the last filtration level before the stack, pressure drop at the last filtration level, low flow rate at the stack) are exceeded.

11.4.9 Final Filtration Units

The final filtration units provide the last stages of HEPA filtration prior to the air being discharged to the stack. These units are installed in the VHD Exhaust System, HD Exhaust System, Process Cell Exhaust System, MD Exhaust System, and Offgas Treatment System. The final filters are capable of operating during a fire in rooms that are exhausted through the filters and to safely handle products of combustion.

Each of the final filtration units consists of a filter assembly housing, a two stage spark arrester, and two stages of HEPA filters. The final filter housings are stainless steel, bag-in/bag-out type and are equipped with necessary test ports to permit in-place testing of HEPA filter stages with dioctyl phthalate (DOP) to monitor system efficiency. Dampers are provided so that filter housings can be completely isolated from the HVAC system during filter replacement.

The first stage spark arrester is made of a stainless steel wire mesh. The second stage spark arrester is made of a stainless steel mesh with interwoven fiberglass designed to remove particles greater than 1 micron. The complete spark arrester assemblies are designed and fabricated to the same temperature ratings as the exhaust pipe/duct in which they are installed. Frames are metallic construction. The spark arresters are fabricated of noncombustible materials and are designed to pass design flow rates under fully loaded conditions without structural failure.

HEPA filters are fabricated of glass media with metallic frames and silicone gaskets. The filters are at least 99.97% efficient and can operate in continuous service at 450°F (232°C). The filters can withstand a differential pressure of 10 in WG (2488 Pa) without failure.

The final filtration units, exhaust plenums, exhaust fans, and associated control devices are located as far as practicable from a postulated fire, where they are not exposed to the fire's direct effects. Redundant trains are located in separate fire areas. The integrity of the final filtration units is not degraded by fire and smoke.

Analyses based on final design are in progress to demonstrate that the HEPA filters are protected from fire and other operating conditions and to demonstrate that the ventilation systems LPF is 10^{-4} or better. See Section 5.4.4.4 for information on operating conditions that will damage HEPA filters.

11.4.10 Design Basis for Non-Principal SSCs

The design of the ventilation and air-conditioning systems is in accordance with the applicable standards and guidelines published by the following organizations:

- Air Moving and Conditioning Association
    - AMCA-99-1986, *Standards Handbook*
- American Conference of Governmental Industrial Hygienists

  - *Industrial Ventilation A Manual of Recommended Practice*, 23rd Edition
- American Society of Heating Refrigeration and Air-Conditioning Engineers
  - ASHRAE 62-1999, *Ventilation for Acceptable Air Quality*
  - ASHRAE 90.1-1989, *Energy Standard for Buildings Except Low-Rise Residential Buildings*
- National Fire Protection Association
  - NFPA 45-1996, *Standard on Fire Protection for Laboratories Using Hazardous Chemicals*
  - NFPA 90A-1996, *Standard for the Installation of Warm Air Heating and Air Conditioning Systems*
- Sheet Metal and Air-Conditioning Contractors National Association
  - SMACNA-1980, *Rectangular Industrial Duct Construction Standards*
  - SMACNA-1999, *Round Industrial Duct Construction Standards.*

Outdoor design temperatures for use in sizing HVAC systems are based on weather data, in accordance with ASHRAE, *1997 Handbook of Fundamentals*, as follows:

• Summer; dry bulb	96°F (.4%); 94°F (1%)
• Summer; mean coincident wet bulb	76°F; 75°F
• Summer, maximum wet bulb	79°F (1%)
• Summer, daily range	20.2°F
• Winter; dry bulb	21°F (99%); 25°F (99.6%).

11.4.11 Design Basis for Principal SSCs

The following sections provide the design bases for the confinement and ventilation systems that are designated as principal SSCs in Chapter 5. The ventilation systems, gloveboxes, process vessels, and other containers used to store and transport plutonium are designed to ensure the confinement of hazardous materials. These systems are designed to limit the release of radioactive material to the environment (including plant operating areas) and to meet the performance requirements of 10 CFR §70.61 for protection of the IOC and workers.

The principal SSCs associated with the confinement and ventilations systems are as follows

<u>Ventilation and Air Conditioning Systems</u>

- C2 Confinement System Passive Barrier
- C3 Confinement System
- C4 Confinement System
- Emergency Control Room Air Conditioning System

- Emergency Generator Ventilation System
- High Depressurization Exhaust System
- Process Cell Exhaust System
- Supply Air System
- MFFF Tornado Dampers
- Offgas Treatment System

Confinements

- 3013 Canister
- 3013 Transport Cask
- Glovebox and Glovebox Pressure Controls (Including Process Safety Control Sub-System pressure alarm function)
- Transfer Containers
- Waste Containers
- Sintering Furnace Confinement Boundary

11.4.11.1 Ventilation and Air-Conditioning Systems

The following ventilation and air-conditioning systems are principal SSCs or have individual components that are principal SSCs:

- VHD Exhaust System
- HD Exhaust System
- Emergency Control Room Air-Conditioning System
- Emergency Generator Building HVAC systems
- Process Cell Exhaust System
- MD Exhaust System components:
  - Final filters
  - Pressure boundary downstream of the final filters
  - Tornado dampers

- Supply Air System components:
  - Emergency air duct
  - Inlet filters
  - Pressure boundary upstream of the inlet filters
  - Tornado dampers
- Offgas Treatment Unit (Scrubbing function is not credited in the accident analysis)
  - Pressure boundary
  - Final filters
  - Exhaust Fans

11.4.11.1.1 Design Basis Standards

The design of the HVAC systems and confinement for the MFFF is consistent with the criteria and design guidance provided in Regulatory Guide 3.12, *General Design Guide for the Ventilation System of Plutonium Processing and Fuel Preparation Plants.* One noted exception to this Regulatory Guide is that there are no adsorbers in the filter lines, therefore the heaters and water mist spray for fire protection of final HEPA filters are not required.

The design of the principal ventilation SSCs is developed in accordance with the following codes and standards (as applicable to each SSC):

- Energy Research and Development Administration
  - ERDA 76-21 *Nuclear Air Cleaning Handbook*, 2nd edition
- American Society of Mechanical Engineers
  - AG-1-1997, *Code on Nuclear Air and Gas Treatment*
  - B31.3- 1996, *Process Piping, including 1998 Addenda*
  - N509-1989 (R1996), *Nuclear Power Plant Air-Cleaning Units and Components*
  - N510-1989 (R1995), *Testing of Nuclear Air-Treatment Systems*
- National Fire Protection Association
  - NFPA 801-1998, *Fire Protection for Facilities Handling Radioactive Materials.*

11.4.11.1.2 C2 Confinement System Passive Barrier

Additional design basis associated with this PSSC is as follows:

- Two stages of HEPA filters prior to discharge to the atmosphere;
- Spark arrestors and prefilters in each final filtration assembly;
- Each HEPA stage shall be field tested to have an efficiency of 99.95 percent (1E-4 analytical assumption);
- Fire-rated dampers between designated fire areas;
- In-place HEPA filter testing capability in accordance with ASME N510 for the final filtration assemblies;

- Final filters and downstream ductwork remain structurally intact during and after design basis earthquakes and withstand the effects of tornadoes.

11.4.11.1.3 C3 Confinement System

Additional design basis associated with this PSSC is as follows:

- C3 zone pressure is maintained at a negative pressure relative to atmosphere during normal and transient operation;
- Designed to maintain system exhaust safety function assuming single active component failure;
- Redundant 100 percent capacity final filter assemblies with two stages of HEPA filters prior to discharge to the atmosphere;
- Spark arrestors and prefilters in each final filter assembly upstream of the HEPA filters;
- Two 100 percent capacity fans in C3 exhaust system;
- Manual or automatic fire-rated dampers between designated fire areas;
- In-place HEPA filter testing capability in accordance with ASME N510 for the final filtration assemblies;
- Each HEPA stage shall be field tested to have an efficiency of 99.95 percent (1E-4 analytical assumption);
- Provide emergency cooling capability for selected areas;
- Fans are powered from normal (non-PSSC), standby (non-PSSC), and emergency power supplies (PSSC);
- Remains operational after facility fires and design basis earthquakes and withstand the effects of tornadoes

11.4.11.1.4 C4 Confinement System

Additional design basis associated with this PSSC is as follows:

- C4 zone pressure maintained at negative pressure with respect to C3 process room during normal operation and transients;
- Designed to maintain system exhaust safety function assuming single active component failure;
- Redundant 100 percent capacity final filter assemblies with two stages of HEPA filters prior to discharge to the atmosphere;
- Spark arrestors and prefilters in each final filter assembly upstream of the HEPA filters;
- Four 100 percent capacity fans in C4 exhaust system;
- Manual actuated fire isolation valves between designated fire areas;
- VHD Exhaust system is designed to maintain a 125-ft/min (38.1-m/min) face velocity across a design basis glovebox breach. The design basis breach is equal to the maximum credible glovebox breach;
- In -place HEPA filter testing capability in accordance with ASME N510 for the final filtration assemblies;
- Each HEPA stage shall be field tested to have an efficiency of 99.95 percent (1E-4 analytical assumption);

- Fans are UPS powered from normal (non-PSSC), standby (non-PSSC), and emergency power supplies (PSSC)

11.4.11.1.5 Emergency Generator Ventilation System

Additional design basis associated with this PSSC is as follows:

- One 100 percent capacity air conditioning unit for each switchgear room;
- One 100 percent capacity roof ventilator for engine room cooling during standby (engine fan cools room during operation);
- Fans are powered from normal (non-PSSC), standby (non-PSSC), and emergency (PSSC) supplies;
- Remains operational after facility fires and design basis earthquakes and withstand the effects of tornadoes

11.4.11.1.6 Emergency Control Room Air Conditioning System

- Maintain habitable environment in emergency control room
- Dual emergency control room air intakes with continuous monitoring for hazardous chemicals
- Maintain a positive pressure with respect to surrounding areas
- One 100 percent capacity (per control room) filtration assembly (using pre-filter, two HEPA filter stages, and chemical filters) for control room air supply
- In-place HEPA filter testing capability for HEPA filter assemblies in accordance with ANSI-N510;
- One 100 percent capacity (per control room) air handling unit;
- One 100 percent capacity exhaust fan and one 100 percent capacity booster fan;
- Each HEPA stage shall be field tested to have an efficiency of 99.95 percent
- Fans are powered from normal (non-PSSC), standby (non-PSSC), and emergency (PSSC) supplies;
- Remains operational during and after facility fires and after design basis earthquakes and withstand the effects of tornadoes

11.4.11.1.7 High Depressurization Exhaust System

See C3 Confinement System above for additional design basis associated with this PSSC.

11.4.11.1.8 Process Cell Exhaust System

Additional design basis associated with this PSSC is as follows:

- Redundant 100 percent capacity final filter assemblies with two stages of HEPA filters prior to discharge to the atmosphere;
- Spark arrestors and prefilters in each final filter assembly upstream of the HEPA filters;
- Each HEPA stage shall be field tested to have an efficiency of 99.95 percent (1E-4 analytical assumption);
- Fire-rated dampers between designated fire areas;

- In-place HEPA filter testing capability in accordance with ASME N510 for the final filtration assemblies;
- Fans are powered from normal (non-PSSC), standby (non-PSSC), and emergency power supplies (PSSC);
- Remains operational after facility fires and design basis earthquakes and withstands the effects of tornadoes
- Two 100 percent capacity fans;
- Process Cell pressure is maintained at a negative pressure relative to atmosphere during normal and transient operation;
- Designed to maintain system exhaust safety function assuming single active component failure.

11.4.11.1.9 Supply Air System

Additional design basis associated with this PSSC is as follows:

- Provide supply air for emergency cooling;
- HEPA filter stages for building air supply for static confinement;
- Each HEPA stage shall be field tested to have an efficiency of 99.95 percent (1E-4 analytical assumption);

11.4.11.1.10 MFFF Tornado Dampers

Additional design basis associated with this PSSC is as follows:

- Withstand the effects of design basis tornadoes;
- Remains operational after facility fires and design basis earthquakes

11.4.11.1.11 Offgas Treatment System

Additional design basis associated with this PSSC is as follows:

- Two stages of HEPA filters prior to discharge to the atmosphere;
- Spark arrestors and prefilters in each final filtration assembly;
- Each HEPA stage shall be field tested to have an efficiency of 99.95 percent (1E-4 analytical assumption);

- In-place HEPA filter testing capability in accordance with ASME N510 for the final filtration assemblies;
- Final filters and ductwork remain structurally intact during and after design basis earthquakes and withstand the effects of tornadoes.

11.4.11.2 Gloveboxes and Glovebox Pressure Controls

Gloveboxes are designed to provide a confinement barrier for hazardous material. They are designed to remain functional during and after a design basis earthquake.

Design provisions that minimize the potential for a breach of confinement resulting from dropped loads include the following:

- Use of highly automated processes with complementary hard-wired logic for safe material handling within the glovebox, which precludes human handling incidents

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- Use of impact-resistant materials for window panels
- Design of the glovebox floor to withstand the impact of potential load drops
- Use of barriers or guides to prevent the fall of containers and other equipment inside the glovebox and to protect windows from external impact.

Gloveboxes and their principal SSCs are designed and fabricated in accordance with the following codes and standards:

- ANSI/AISC N690-1994, *Specification for the Design, Fabrication and Erection of Safety Related Steel Structures for Nuclear Facilities* as described below. In general, the following requirements are excluded: materials, hole spacing and edge distance, fastener sizes, tolerances and fabrication.
- AWS D1.1-1998, *Structural Welding Code*
- AWS D1.6-1999, *Structural Welding Code-Stainless Steel*
- EJMA-1993, *Standards of the Expansion Joint Manufacturer's Association*, Sixth Edition
- Roark and Young, *Formulas for Stress and Strain*, 5th Edition, McGraw-Hill, Inc., 1975
- *USS Steel Design Manual*, US Steel Corporation, January 1981.

Loads and Forces are in accordance with AISC N690, Section Q1.3, except only the loads and forces applicable to the gloveboxes are included.

Load Combinations and Stress Limit Coefficients are in accordance with AISC N690 Table Q1.5.7.1, except for the following:

- Self-equilibrating stresses considered in gloveboxes and process equipment structural analyses are those due to the thermal expansion of gloveboxes, equipment, and distribution systems, where significant.
- Accident conditions consist of worst case reaction, temperature, and pressure loads occurring simultaneously under different accident scenarios. Multiple scenarios may be evaluated to determine the bounding set of accident conditions.
- Abnormal Extreme loading combination is used to evaluate capacity of SSCs that must withstand Design Earthquake with no gross structural failure. Limited plastic deformation is allowed for these cases.
- The total seismic inertia load case, determined by combining the results from acceleration loading in spatial direction by SRSS, is absolutely summed with the results of other load cases calculated statically, including the seismic anchor movement load case.

Design requirements, including allowable stress criteria, are determined in accordance with applicable parts of AISC N690 Sections Q1.5 and Q1.6, except for the following:

- Local peak stresses that occur at structural discontinuities may be determined based on published empirical solutions, such as Formulas for Stress and Strain.

- Compression allowable stresses in flat shell wall elements may be determined based on the critical elastic buckling stress using equation(s) taken from the USS Steel Design Manual.
- Buckling analysis codes may be used to evaluate buckling stresses.
- Plate equivalent stress evaluations may be used for the qualification of plate elements.
- Design and fabrication of welds in carbon steel are in accordance with AWS D1.1 as modified by N690 Section Q1.17.
- Design and fabrication of welds in stainless steel are in accordance with AWS D1.6 as modified by N690 Section Q1.17.
- Section Q1.6.3.2 (a) is used for combined tensile and shear stresses in fasteners. Stresses in bolted fasteners connections are calculated based on the worst case combination of tensile and shear loads, including tension caused by prying action produced by deformation of the connected parts.
- Thread shear evaluations are used in the design of fasteners. AISC N 690 includes no provisions for the evaluation of thread shear in fasteners and tapped holes.
- Bellows connecting gloveboxes are designed and fabricated in accordance with EJMA-1993.

Inspection of full-penetration welds meets the requirements in AISC N690, Q1.26.2.1. Inspection of partial-penetration welds meets the requirements in AISC N690, Q1.26.2.2. Other weld inspection is in accordance with AWS D1.1 for carbon steel and AWS D1.6 for stainless steel.

Gloveboxes are designed with pressure/vacuum-relief devices that prevent over-pressurizing gloveboxes and excessive negative pressures.

The glovebox ventilation will provide sufficient flow to compensate for in-leakage rate of 0.25 percent of the glovebox volume per hour at -4.0 in WG (-1000 Pa).

Redundant pressure sensors monitor differential pressure with respect to the process room and alert the operators to upset conditions. The instruments remain operational following facility fires in unaffected areas, tornadoes, and design basis earthquakes.

11.4.11.3 3013 Canisters

The 3013 inner and outer canisters are designed according to the specifications in DOE-STD-3013-2000, *Stabilization, Packaging, and Storage of Plutonium-Bearing Materials.*

11.4.11.4 3013 Transport Casks

The 3013 Transport casks are designed for applicable requirements of 10 CFR Part 71.

11.4.11.5 MOX Fuel Transport Cask

The MOX fuel transport casks are designed and certified separately in accordance with 10 CFR Part 71.

11.4.11.6 Waste Containers

MOX transuranic wastes are packaged in waste containers designed to DOT Type A Specification 7A and are vented and filtered, as appropriate.

11.4.11.7 Transfer Containers

Transfer containers are designed to withstand applicable events. These events will be identified in the ISA.

11.4.11.8 Sintering Furnace Confinement Boundary

The sintering furnace provides a primary confinement boundary function. The design basis for the sintering furnace is as follows:

The seals for the sintering furnace are designed for peak temperature of 316°C. The furnace is shutdown with no damage to the confinement barrier if overheating or low cooling flow conditions exist.

The furnace shell and airlocks are designed to withstand an over pressure of 2.5 bar (36.3 psi). The furnace shell leak tightness is specified at 5E-5 leaked vol/hr at 2.2 psi. To prevent furnace overpressure conditions, the following controls are implemented:

- High humidifier water level isolates the humidifier water feed line to prevent excessive moisture carryover to the furnace and subsequent over pressure due to rapid steam generation.
- Hydrogen hazards are prevented as discussed in Section 8.5.
- The furnace is designed to operate at a slight overpressure. Pressure control and overpressure protection are provided by redundant pressures controls.
- The furnace is designed to maintain its confinement function during the design basis earthquake.

11.4.11.9 Process Cell

Process cell leak confinement is performed by drip trays. The drip tray design basis is to contain the maximum inventory of the largest vessel in the cell. Drip trays are fully welded and designed to withstand a design basis earthquake.

11.7 MATERIAL-HANDLING EQUIPMENT

This section describes the functional requirements and design bases for MFFF equipment designed to transfer MOX fuel production material in a dry, solid form. Handling equipment used to process material in an aqueous form is described in Section 11.8. Heavy lift cranes are described in Section 11.10.

The equipment addressed in this section is located inside of the MP Area and the Shipping and Receiving Area. The equipment includes all devices, actuating mechanisms, and support structures engaged in the transfer of MP process materials, either located inside of or installed outside of process gloveboxes. Controls that monitor and drive material-handling equipment are included as part of the equipment functional descriptions in this section. General requirements and descriptions for the overall process control system are provided in Section 11.6.

11.7.1 Function

Material-handling systems are required to perform both safety and nonsafety functions. The principal SSCs and associated safety function for the material-handling equipment are identified in Chapter 5. Safety functions are maintained during normal operations, upset conditions, accidents, and natural phenomena events. Nonsafety functions are normally only performed during specific operating modes or equipment configurations.

The functions assigned to material-handling system elements include the following:

- Transfer MOX fuel material and components from one point in the process to another, in accordance with process throughput, positioning tolerance, mechanism reliability, and radiological shielding requirements
- Maintain structural integrity and control of process containers to ensure that the confinement boundary is not breached
- Maintain structural integrity and control of process containers to ensure that criticality control functions are performed
- As necessary, work with fire barriers to transfer material across process atmosphere or fire area boundaries
- During maintenance operations, transfer tooling and equipment spare parts from point to point inside the glovebox system.

11.7.2 Description

Several different types of equipment are used to move material from one point in the MP process to another, based on the form of the product, the container used to carry it, and the configuration of the process equipment that receives the container. General descriptions of the MP and AP processes are provided in Sections 11.2 and 11.3, respectively.

Fuel production material in the MP process portion of the plant appears in one of five general forms: powder, pellets, rods, assemblies, and waste. Each material form must be transferred inside of containers designed to meet applicable confinement, criticality, and shielding requirements.

11.7.2.1 Powder Handling Equipment

Fuel production powder materials handled in the MP process include the plutonium oxide and depleted uranium oxide feed materials, zinc stearate and poreformer additives used to improve powder workability and control density, and dusts recovered from glovebox enclosures and returned to the fuel production process. Plutonium oxide powders are received at the facility packed in qualified shipping packages. Each shipping package holds a single container designed to meet the requirements of DOE-STD-3013-2000. Upon receipt, the containers are removed from the shipping package, assayed, and stored until ready for use. When required by the process, the containers are removed from storage and introduced into the glovebox system. Depleted uranium powders are received and handled in sealed vinyl bags packed in drums. The zinc stearate and poreformer additives are also received in sealed containers. These materials are introduced to the glovebox system via airlocks.

Equipment used to handle palletized shipping packages includes forklifts, turntables, and bridge cranes. Individual shipping packages are transported by forklifts equipped with drum grips and roller conveyor systems. 3013 containers outside of gloveboxes are handled by automated pick-and-place cranes and robots, slide tables, or roller conveyors. Inside of glovebox enclosures, powder materials are transported inside of convenience cans, food cans, reusable cans, dust pots, sample vials, or in one of a series of powder jars. Convenience cans, reusable cans, and sample vials are loaded into shuttles that are transferred pneumatically from one glovebox to another. Powder jars and dust pots are transferred between gloveboxes inside of shielded transfer casks along sections of live roller conveyor. Elevators and rotary tilters are used to raise, lower, or dump jars as required for emptying, filling, and weighing. Powder is also transported in bulk form over short distances by gravity feed, vibrating conveyor, and direct pneumatic transfer.

Material-handling equipment designed to carry powder containers and pallets include roller conveyors, ball-screw elevators, pick-and-place robots equipped with gripping manipulators, and pneumatic transfer systems. Roller conveyor and elevator systems installed inside of glovebox enclosures are equipped with positive stops and guide rails to prevent interaction between the load and the walls or floor of the glovebox confinement boundary. Confinement for powder materials handled outside of the glovebox enclosure is provided by the container, which is qualified for a drop from heights greater than the handling height. Confinement for powder materials handled inside glovebox enclosures is provided by the enclosure. Confinement for material inside of pneumatic transfer systems is provided by system piping. Pneumatic transfer piping located in C2 areas only is to be designed with double wall pipe with high priority on avoiding routing through C2 areas. Any double wall pipe located in a C2 area will be provided with a 2-hour fire rated barrier. The passive fire barriers (UL-1 approved) are QL-1a IROFS. All pneumatic transfer piping located in all other confinement zones may be single wall stainless steel pipe with welded connections.

11.7.2.2 Pellet Handling Equipment

Fuel pellets are transported either individually on belts, vibrating conveyors, or by robot, in bulk in open-topped molybdenum boats or stainless steel boxes, or lined up on trays that are stacked, covered, and transported as an assembly. The molybdenum boats and stainless steel boxes carry a maximum of 10 kg and 20 kg of pellets, respectively. Tray assemblies consist of 10 trays of pellets, each of which has 12 rows of pellets, 350 mm in length.

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11.7.5 System Interfaces

Material-handling equipment shares interfaces with many process unit components, as well as external utility supply and control systems. Process unit components include major process equipment items, the glovebox enclosure, and instrumentation and controls. Physical and functional interfaces between these elements include the following:

- Structural connections that support the equipment
- Mechanical penetrations through which motion is transferred
- Electrical connections between process controls and motors, actuators, and sensors
- Transfer points where control of material containers is passed from one device to the next
- Windows and glove ports in the glovebox boundary, which provide visual and physical access to equipment for maintenance.

Interfaces between material-handling equipment and external utility systems include connections between motors and electrical power, the compressed nitrogen supply to pneumatic actuators inside the glovebox, supply of the hydrogen-argon atmosphere to the sintering furnace, and the glovebox and other ventilation systems, which maintain temperatures and pressure differentials within prescribed limits.

11.7.6 Design Basis for Non-Principal SSCs

Material-handling systems and their supports are designed, fabricated, and qualified to perform required functions in accordance with the following national codes and standards:

- **Structural Integrity** – Components required to maintain structural integrity are designed and qualified in accordance with AISC ASD, *Manual of Steel Construction, Allowable Stress Design*, 9th Edition, 1989, as described below. In general, the following requirements are excluded: materials, hole spacing and edge distance, fastener sizes, tolerances, and fabrication.

- **Cranes** – Overhead cranes are designed in accordance with ASME B30.2-1996, *Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist Overhead and Gantry Cranes*. Bridge cranes comply with CMAA-70-1994, *Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes*. and CMAA-74-1994, *Specification for Top Running and Under Running Single Girder Electric Overhead Traveling Cranes Utilizing Under Running Trolley Hoist*. Lifting hooks are designed in accordance with ASME B30.10-1999, *Hooks*.
- **Hoisting Equipment** – Hoists are designed in accordance with ASME B30.16-1998, *Overhead Hoists*.
- **Structural Integrity and Fabrication** – AWS D1.1-1998, *Structural Welding Code*
- **Structural Integrity and Fabrication** – AWS D1.6-1999, *Structural Welding Code-Stainless Steel*

- **Structural Integrity and Fabrication** – AWS D14.1-1997, *Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment*
- **Seismic Loading** – UBC-1997, *Uniform Building Code*
- **Seismic Design** – ASME-NOG-1-1998, *Rules for the Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)* as described below.

ASME B30.2, ASME B30.10, ASME B30.16, and CMAA-74 do not apply for process materials handling equipment, which raises and transports loads using fixed geometry mechanisms.

Mechanical equipment machine components for material handling equipment, drive train machine components, actuators, and load path components are sized for normal loads based upon strength of materials, deflection, and fatigue criteria given in Section 70-4 of CMAA-70-1994. Mechanical equipment credited with performing interaction prevention functions, in addition to their normal operating requirements, is seismically qualified using the allowable stresses specified in ASME-NOG-1-1998. Commercial components may be qualified based on the manufacturer rated loads, or by other more specific load capacity information or analyses provided by the vendor.

For commercial quality level, non-crane and non-hoist process equipment supports, piping supports, electrical and instrument supports, loading combinations, and allowable stress factors are in accordance with AISC-ASD Section A5.2 and Chapters D through K. Seismic force is based on UBC-97.

AISC-ASD Section J3.5 is used for combined tensile and shear stresses in fasteners. Stresses in bolted fastener connections are calculated based on the worst case combination of tensile and shear loads, including tension caused by prying action produced by deformation of the connected parts.

Design and fabrication of welds for non-crane/non-hoist equipment/systems supports in carbon steel are in accordance with AWS D1.1 as modified by AISC ASD, Chapter J.

Design and fabrication of welds for non-crane/non-hoist equipment/systems supports in stainless steel are in accordance with AWS D1.6 as modified by AISC ASD, Chapter J.

Design and fabrication of welds for cranes and hoists are in accordance with AWS D1.1 as modified by AWS D14.1 and as applicable, CMAA-70 or CMAA-74.

Material handling equipment installed inside the gloveboxes is designed to meet glovebox material and surface finish requirements and to function under the conditions found in the glovebox interiors. MOX powder, dust, or debris buildup on handling equipment installed inside gloveboxes is limited by design. In addition, material-handling equipment decontamination is facilitated by design (e.g., the mounting of a stainless steel casing to prevent powder/dust retention on material handling support structures). Also, equipment is easily visible, accessible, and dismantled for maintainability and decontamination. Sealed bearings or leak-free coupling mechanisms are used when appropriate. Lubricant use is limited to the extent practical. The surface quality or coating of equipment minimizes powder/dust retention and facilitate

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cleaning/decontamination. Internal welds are continuous and ground smooth, and re-entrant corners have a large radius. A portable vacuum cleaner or glovebox vacuum network (for some powder processing gloveboxes) is used to minimize powder/dust retention and used to cleanup any spilled powder or dust.

Material handling equipment installed outside of gloveboxes but in C3b process rooms have painting applied, as necessary, to facilitate decontamination.

Maintenance cranes and maintenance hoists are not qualified to retain their loads under seismic conditions. Special provisions (e.g., operator protective equipment, removal of radioactive material from glovebox) are in place for maintenance crane/hoist lifts. Criticality prevention elements need not be qualified to withstand maintenance load drops, since it is assumed that all, or significant quantities of, nuclear materials are removed from the glovebox system and/or area isolated during maintenance.

11.7.7 Design Basis for Principal SSCs

Material-handling systems that are designated as principal SSCs are designed and qualified to perform their safety functions during normal operations, upset conditions, and design basis events.

The general design principles that apply to systems required to perform criticality safety functions are discussed in Chapter 6. Criticality controls on the material-handling system will be developed as part of the detailed design.

Material-handling equipment and support structural members are designed to prevent physical interaction with confinement boundary elements or principal SSCs under worst-case loading associated with normal, upset, and design basis events.

To prevent physical interaction, the following design principles are applied:

- Equipment inside and outside gloveboxes is designed to be supported in such a way as to maintain clearance between the equipment and the confinement boundary under all conditions, including preventing uncontrolled motion of objects capable of breaching the confinement boundary.
- Physical stops are incorporated in material-handling equipment designs to prevent the uncontrolled motion of payloads capable of breaching confinement in the event of over-travel or seismic conditions.
- Equipment that utilizes actuating mechanisms to grip payloads capable of breaching confinement is designed to ensure that the mechanisms retain the payload under all conditions, including loss-of-power events and seismic conditions.
- Equipment used to hoist loads that could impact confinement boundary elements is designed and qualified with appropriate margins of safety.

All material-handling equipment will be operated in accordance with Material Handling Controls as described in Section 5.6.2.3.

Codes and standards used to qualify material transport principal SSCs include the following:

- **Structural Integrity** – Components required to maintain structural integrity are designed and qualified in accordance with ANSI/AISC N690-1994, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities*, as described below. In general, the following requirements are excluded: materials, hole spacing and edge distance, fastener sizes, tolerances, and fabrication.

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- **Cranes** – Overhead cranes are designed in accordance with ASME B30.2-1996, *Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist Overhead and Gantry Cranes.* Bridge cranes comply with CMAA-70-1994, *Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes,* and CMAA-74-1994, *Specification for Top Running and Under Running Single Girder Electric Overhead Traveling Cranes Utilizing Under Running Trolley Hoist.* Bridge cranes also comply with NUREG-0554, *Single Failure Proof Cranes at Nuclear Power Plants.*
- **Hoisting Equipment** – Hoists are designed in accordance with ASME B30.16-1998, *Overhead Hoists.*
- **Seismic Design** – ASME-NOG-1-1998, Rules for the Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder) as described below.
- **Structural Integrity and Fabrication** – AWS D1.1-1998, *Structural Welding Code*
- **Structural Integrity and Fabrication** – AWS D1.6-1999, *Structural Welding Code-Stainless Steel*
- **Structural Integrity and Fabrication** – AWS D14.1-1997, Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment.
- Structural Integrity – Roark and Young, Formulas for Stress and Strain, 5th Edition, McGraw-Hill, Inc., 1975.

ASME B30.2, ASME B30.16, and CMAA-74 do not apply for process materials handling equipment, which raises and transports loads using fixed geometry mechanisms.

Loads and Forces are in accordance with AISC N690, Section Q1.3, with the exception that only the loads and forces applicable to the materials handling equipment associated with process gloveboxes are included.

Ductility requirements for impact evaluation are in accordance with AISC N690, Table Q1.5.8.1.

Load Combinations and Stress Limit Coefficients are in accordance with AISC N690, Table Q1.5.7.1, except for the following:

- Self-equilibrating stresses considered in gloveboxes and process equipment structural analyses are those due to the thermal expansion of gloveboxes, equipment, and distribution systems, where significant.
- Accident conditions consist of worst case reaction, temperature, and pressure loads occurring simultaneously under different accident scenarios. Multiple scenarios may be evaluated to determine the bounding set of accident conditions.
- Abnormal Extreme loading combination is used to evaluate capacity of SSCs that must withstand design earthquake with no gross structural failure. Limited plastic deformation is allowed for these cases.

- The total seismic inertia load case, determined by combining the results from acceleration loading in spatial direction by SRSS, is absolutely summed with the results of other load cases calculated statically, including the seismic anchor movement load case.

Design requirements, including allowable stress criteria, are determined in accordance with applicable parts of AISC N690 Sections Q1.5 and Q1.6 except for the following:

- Local peak stresses that occur at structural discontinuities may be determined based on published empirical solutions, such as *Formulas for Stress and Strain.*
- Buckling analysis codes may be used to evaluate buckling stresses.
- Plate equivalent stress evaluations may be used for the qualification of plate elements.
- Design and fabrication of welds for equipment/systems supports in carbon steel are in accordance with AWS D1.1 as modified by N690 Section Q1.17.
- Design and fabrication of welds for equipment/systems supports in stainless steel are in accordance with AWS D1.6 as modified by N690 Section Q1.17.
- Design and fabrication of welds for hoists are in accordance with AWS D1.1 as modified by AWS D14.1 and as applicable, CMAA-70 or CMAA-74.
- Section Q1.6.3.2 (a) is used for combined tensile and shear stresses in fasteners. Stresses in bolted fasteners connections are calculated based on the worst case combination of tensile and shear loads, including tension caused by prying action produced by deformation of the connected parts.
- Thread shear evaluations are used in the design of fasteners. AISC N 690 includes no provisions for the evaluation of thread shear in fasteners and tapped holes.
- Mechanical equipment structural members such as crane bridge members and robotic arms and masts are qualified for load retention functions for normal loading in accordance with Section 70-3 of CMAA-70-1994 and for seismic loading in accordance with ASME-NOG-1-1998.
- Mechanical equipment machine components including material handling equipment, drive train machine components, actuators, and load path components are sized for normal loads based upon strength of materials, deflection, and fatigue criteria given in Section 70-4 of CMAA-70-1994. Mechanical equipment credited with performing safety and interaction prevention load retention functions in addition to their normal operating requirements are seismically qualified using the allowable stresses specified in ASME-NOG-1-1998. Commercial components may be qualified based on the manufacturer rated loads or by other more specific load capacity information or analyses provided by the vendor.

Inspection of full-penetration welds meets the requirements in AISC N690, Q1.26.2.1. Inspection of partial-penetration welds meets the requirements in AISC N690, Q1.26.2.2. Other weld inspection is in accordance with AWS D1.1 for structural welds in carbon steel, AWS D1.6 for structural welds in stainless steel, and AWS D14.1 for hoisting equipment welds.

The primary means of detecting contaminated fluid in-leakage from the process systems into the Process Chilled Water system internal cooling loops is by radiation detection in a continuous bypass flowpath in the common chilled water return line of each internal cooling loop. The chilled water return lines of each internal cooling loop is continuously monitored with radiation alarms in the main control room.

Figure 11.9-2 provides a schematic of the Process Chilled Water System.

11.9.1.2.3 Major Components

The major components of the Process Chilled Water System are as follows:

- **Process Chillers** –Multiple, parallel, air-cooled process chillers are used to supply the required chilled water to the air compressors and process cooling coils. The maximum process-cooling load is approximately 125 tons, allowing at least one chiller to be in standby or maintenance mode for reliability. The chillers are placed in service and loaded as operationally required by automatic load controllers sensing chiller outlet temperature. These chillers are located outside of the MOX Fuel Fabrication Building.
- **Circulating Pumps** – Multiple, parallel sets of centrifugal circulating pumps are provided for the external cooling loop and each of the internal cooling loops.
- **Intermediate Heat Exchangers** – These heat exchangers provide cooling water to process cooling coils while maintaining separation from areas requiring moderation control to prevent criticality and the potential spread of contamination to the outside environment via the external cooling loop.

11.9.1.2.4 Control Concepts

The Process Chilled Water System is controlled from the Utilities Control Room (B-319) or the Remote Auxiliary Utilities Control Room (D-301) as described in Section 11.6.2.5. The control concepts for the Process Chilled Water System are as follows:

- **Process Chiller Operation and Load Control** – The process chillers are placed in service and loaded as operationally required by automatic load controllers sensing chiller outlet temperature.
- **MOX Fuel Fabrication Building Isolation** – The chilled water penetrations into and out of the MOX Fuel Fabrication Building are provided with redundant seismically operated isolating valves to prevent flooding.

11.9.1.2.5 System Interfaces

The CHP System interfaces with the following structures, systems, and components (SSCs). These interfaces are either supplied to CHP components for support and operation of the CHP System or are supplied from the CHP System for AP, MP, Utility or Reagent Systems process and component cooling.

ELECTRICAL POWER - CHP System components interface with the Electrical Distribution System for electrical power as the motive force to operate major components and as control power for instrumentation and controls.

INSTRUMENT AIR (IAS) SYSTEM - Instrument Air is supplied to the CHP System air operated valves as motive air for valve operation.

DEMINERALIZED WATER (DMW) SYSTEM - The Demineralized Water System (DMW) supplies demineralized water to the CHP external and internal cooling loops surge tanks for initial fill, refill after maintenance, and for make-up during normal operation. Make-up is initiated remotely by the Operators based on level instrument on each surge tank.

SEISMIC DETECTORS - which provide a signal to the redundant isolation valves to automatically isolate the chilled water penetrations into and out of the MOX Fuel Fabrication Building during a seismic event.

Process chilled water provides cooling to the following users:

- Vacuum Radiation Monitoring (VRM) System
- Process Steam & Condensate (SPS) System
- Hydrazine (RHZ) System
- Precipitation, Filtration And Calcination (KCA) System
- Oxalic Acid Recovery (KCD) System
- Plutonium Dissolution (KDB) System
- Dechlorination and Dissolution Unit (KDD)
- Purification Cycle (KPA) System
- Solvent Recovery (KPB) System
- Acid Recovery (KPC) System
- Waste Collection & Transfer (KWD) System
- MOX Process Components (Sintering Furnaces and Pelletizing unit)
- Aqueous Polishing and MOX Process Laboratory Testing Systems.

11.9.1.3 Demineralized Water System

11.9.1.3.1 Function

The function of the Demineralized Water System is to supply demineralized water to process equipment and utility systems. The Demineralized Water System produces, stores, and transfers pressurized and gravity-fed (i.e., unpressurized) demineralized water to process equipment and utility systems for use in reagent preparation, solutions dilution, internal loop filling, humidification of sintering gas, general laboratory use, sintering furnaces, and miscellaneous process purposes.

11.9.1.3.2 Description

Demineralized water is supplied to the MOX Fuel Fabrication Building by SRS and is stored in a local Demineralized Water System storage tank for onsite usage. Transfer pumps send demineralized water to the AP Area through the Reagent Processing Building Demineralized Water System break pot in the Reagent Processing Building to provide a constant gravity head to various Reagent Processing Building users. The pumps also supply pressurized demineralized water for general laboratory use, for miscellaneous rinsing, and for filling the internal loops of the HVAC and Process Chilled Water Systems and the Process Hot Water System loops.

The buffer tank for the AP Area Demineralized Water System provides storage capacity for users in the AP Area. This tank is equipped with a level control system similar to the level control on the storage tank. The pumps for the AP Area Demineralized Water System recirculate the demineralized water through the break pot. The break pot is used to supply the atmospheric pressure users in the AP Area.

Figure 11.9-3 provides a schematic of the Demineralized Water System.

11.9.1.3.3 Major Components

The major components of the Demineralized Water System are as follows:

- **Demineralized Water System Storage Tank** – The Demineralized Water System storage tank is a storage tank for the Reagent Processing Building that receives and stores demineralized water from SRS and provides the net positive suction head for the transfer pumps. Storage capacity includes providing enough demineralized water for buffer tank initial fill and makeup for the HVAC Chilled Water System, Process Chilled Water System, Process Hot Water System, and AP Area Demineralized Water System, as well as for general laboratory usage and miscellaneous rinsing.
- **Transfer Pumps** – Parallel pumps in the Reagent Processing Building Demineralized Water System supply pressurized demineralized water to the various users and recirculate demineralized water through the Reagent Processing Building break pot. Pumps in the AP Area Demineralized Water System recirculate demineralized water through AP Area break pots.
- **Buffer Tank** – The AP Area buffer tank is used to supply users in the AP Area. Buffer tank refill is controlled by a level control system.
- **Break Pots** – Reagent Processing Building and AP Area break pots are used to supply atmospheric pressure users in the Reagent Processing Building and AP Area, respectively. To maintain a constant head for the users at all times, demineralized water is continuously recirculated through the break pots using the respective transfer pumps.

11.9.1.3.4 Control Concepts

An operator will operate and control the Demineralized Water system (DMW) from a monitor in the main control room, and a local operator in the process area can monitor the DMW system's operation from local control panel(s). The local operator can manually perform limited operations (e.g., loading, pouring, etc).

The control concepts for the Demineralized Water System are as follows:

- **Storage and Buffer Tank Level Control** – To maintain adequate supply in the storage and buffer tanks, each tank contains high- and low-level instrumentation to automatically open or close the makeup valves, as needed.
- **MOX Fuel Fabrication Building Isolation** – The demineralized water penetrations into the MOX Fuel Fabrication Building are provided with double isolating valves to automatically isolate during a seismic event.

11.9.1.3.5 System Interfaces

The Demineralized Water System interfaces with SRS for supply. The Demineralized Water System interfaces with the various Reagent Systems as follows:

- Nitric Acid System
- Hydroxylamine Nitrate System
- Oxalic Acid System
- Silver Nitrate System
- Sodium Hydroxide System
- Hydrazine System
- Hydrogen Peroxide System
- Uranyl Nitrate System.

The Demineralized Water System interfaces with the following Mechanical Utility Systems for loop filling and makeup:

- Process Chilled Water System
- HVAC Chilled Water System
- Process Hot Water System.

The Demineralized Water System interfaces with the following process systems in the AP Area:

- KPC (Acid Recovery)
- KDB (Dissolution)

The Demineralized Water System interfaces with the following miscellaneous equipment:

- Sintering furnace where it is used for humidification of the scavenging gas and emergency cooling
- Laboratory for general laboratory use
- Normal Power Supply
- Seismic detectors, which provide a signal to the redundant isolation valves to automatically isolate the demineralized water system penetrations into and out of the MOX Fuel Fabrication Building during a seismic event.

11.9.1.5 Process Steam System

11.9.1.5.1 Function

The function of the Process Steam System is to transfer and regulate the primary steam supplied by SRS and the Acid Recovery Unit secondary steam to the users in the AP Area. The primary steam users are the KPA and KPC steam jets and to KPA, KCA and KPB hot water heat exchangers. A secondary steam loop is used for the KCD and KPC evaporators.

In addition, the Process Condensate produced from the KPA, KCA and KPB hot water heat exchangers and from the secondary steam loop vaporizers is collected, cooled and transferred to the site storm drain system.

11.9.1.5.2 Description

The Process Steam System provides regulated primary and secondary steam that is supplied to process equipment in the HWS, KPA, KPC, KDB, and KCD Units. In addition, condensate is returned and cooled for discharge to the site storm drain.

Primary Steam - Steam is furnished from the SRS host site. The primary steam is reduced through a pressure control valve for the primary steam header. Steam is further reduced to provide for the occasional use of KPA and KPC steam jets, and is reduced more for use in the KPA, KCA, and KPB hot water exchangers, as well as for the secondary steam loop vaporizer.

Secondary Steam - Provides heating steam to the secondary steam vaporizers. Steam produced in the secondary steam vaporizers is supplied through a pressure reducer for use in the KCD and KPC evaporators.

Process Condensate - This consists of the Condensate Drain Tank and the Condensate Drain Pumps. The drain tank collects the condensate produced from the KPA, KCA, and KPB hot water exchangers and secondary steam loop vaporizers. The drain pumps take their suction from the drain tank and transfer the condensate to the Site Storm Drain System.

The primary means of detecting contaminated fluid in-leakage from the process systems into the condensate returns is by radiation detection in a continuous bypass flow-path in these return lines. The return lines are continuously monitored with radiation alarms in the main control room.

Figure 11.9-5 provides a schematic of the Process Steam and Process Condensate Systems.

11.9.1.5.3 Major Components

The major components of the Process Steam System are as follows:

- Secondary steam vaporizer
- Secondary condensate pumps
- Secondary condensate vent condenser
- Secondary condensate tank
- Primary condensate tank
- Primary condensate vent condenser
- Primary condensate pumps
- Primary condensate cooler
- Condensate Gamma Monitors

11.9.1.5.4 Control Concepts

Normal Operation – The Process Steam and Condensate (SPS) System normally operates permanently. The process is stopped if the equipment temperature is not compliant.

Emergency and Upset Operation – There are no emergency operating modes for the SPS System.

During an upset condition, the system is out of service.

On loss of normal power, the low temperatures require shutting down both the SPS System and the user processes dependent upon the SPS.

On loss of instrument air, all of the air-operated valves fail closed.

All pumps stop and valves close if the PLC fails resulting in the SPS and user processes being stopped until the problem is resolved.

- **MOX Fuel Fabrication Building Isolation** – The Process Steam and Condensate return penetrations into the MOX Fuel Fabrication Building are provided with double shutoff, isolating valves to automatically isolate during a seismic event.

11.9.1.5.5 System Interfaces

The Process Steam System interfaces with the following:

- Chilled Process Water
- Decontamination (DCS)
- Demineralized Water (DMW)
- Hot Water System (HWS)
- HVAC air supply to drain pots SPS-TK2660 and TK2670.
- Oxalic Mother Liquor Recovery (KCD)
- Dissolution (KDB)
- Purification/Oxidation (KPA)
- Solvent Recovery Cycle (KPB)
- Waste Organic Solvent (KWS)
- Acid Recovery (KPC)
- Waste Collection and Transfer (KWD)

The No. 2 diesel fuel oil is supplied to the day tanks for each generator within the Emergency Diesel Generator Building. Each fuel oil day tank is sized for a maximum storage capacity of 660 gal (2,500 L) in accordance with NFPA 37 Section 5-3.2.

Figure 11.9-7 provides a schematic of Emergency Diesel Generator Fuel Oil System.

11.9.1.7.3 Major Components

The major components of the Emergency Diesel Generator Fuel Oil System are as follows:

- **Fuel Oil Storage Tanks** – Each emergency diesel generator is provided with an individual fuel oil storage tank. These storage tanks receive, store, and supply fuel oil for the emergency diesel generators. The fuel oil storage tank is a horizontal, cylindrical tank located in an individual compartment of a protected enclosure. The fuel oil storage tank has a minimum working capacity based on providing a continuous fuel supply for seven days of full load operation for one emergency diesel generator plus an additional operational margin to allow for periodic testing of each emergency diesel generator.
- **Fuel Oil Day Tanks** – Each emergency diesel generator is provided with an individual, immediate-use fuel oil day tank supplied from its fuel oil storage tank via individual supply lines and transfer pumps. Both tanks are located in individual diked areas of the Emergency Diesel Generator Building near their associated diesel generators. Each fuel oil day tank is sized for a maximum storage capacity of 660 gal (2,500 L) in accordance with NFPA 37 Section 5-3.2.
- **Fuel Oil Transfer Pumps** – Each emergency diesel generator is provided with an individual, dedicated fuel oil transfer pump to transfer fuel oil from the common fuel oil storage tank to each diesel via its fuel oil day tank. Each pump is a 100% capacity, positive displacement, screw pump capable of delivering at least the full load fuel requirements of an emergency diesel generator plus an excess operational capacity margin to allow fill or pump-down within a reasonable amount of time. These pumps are located in individual compartments of the protected fuel oil storage tank enclosure.

11.9.1.7.4 Control Concepts

The control concepts for the Emergency Diesel Generator Fuel Oil System are as follows:

- **Fuel Oil Day Tank Level Control** – To maintain correct levels, each fuel oil day tank contains high- and low-level instrumentation to automatically start or stop the associated fuel oil transfer pump, as needed.
- **Level Indication/Alarms** – The fuel oil storage tank and each day tank contain level instrumentation and alarms to monitor high or low tank levels locally in the Emergency Diesel Generator Building, in the A and B Emergency Control Rooms, and at the remote fill station.

11.9.1.7.5 System Interfaces

The Emergency Fuel System interfaces with the following:

- **Emergency Diesel Generators** – The Emergency Diesel Generator Fuel Oil System supplies fuel oil to the generator fuel inlet.
- Emergency Electrical Power Supply.

11.9.1.8 Standby Diesel Generator Fuel Oil System

11.9.1.8.1 Function

The function of the Standby Diesel Generator Fuel Oil System is to receive, sample, store, and transfer fuel oil to the standby diesel generators. The Standby Diesel Generator Fuel Oil System supplies diesel fuel oil to the standby generators that are used to provide the onsite power source for the major electrical loads in the event of loss of primary power. An exhaust system for each generator removes exhaust fumes and dampens noise produced by fuel combustion and is included as part of the manufacturer's supply.

11.9.1.8.2 Description

The Standby Diesel Generator Fuel Oil System receives, samples, stores, and supplies fuel oil to the standby diesel generators. The Standby Diesel Generator Fuel Oil System consists of a buried double-walled bulk storage tank, dual pumps, suction strainers, dual cartridge-type filters, piping, valves, and controls. The bulk storage tank is sized to supply fuel oil for 24 hours of continuous usage for both standby diesel generators operating at full load plus an operational margin to allow periodic testing. The No. 2 fuel oil is supplied to the day tanks for each generator within the Standby Diesel Generator Building. Each fuel oil day tank is sized for a maximum storage capacity of 660 gal (2,500 L) in accordance with NFPA 37 Section 5-3.2 or a maximum of 1,320 gal (5,000 L) total (for both day tanks).

Independent, redundant, fuel oil transfer pumps and associated fuel oil lines are used to prevent single failures from causing the loss of the standby electrical power supply.

Figure 11.9-8 provides a schematic of Standby Diesel Generator Fuel Oil System.

11.9.1.8.3 Major Components

The major components of the Standby Diesel Generator Fuel Oil System are as follows:

- **Fuel Oil Storage Tank** – This common, direct buried, underground storage tank receives, stores, and supplies fuel oil for both standby diesel generators. The fuel oil storage tank has a minimum working capacity based on providing fuel for 24 hours of full load operation for both standby diesel generators plus an additional operational margin to allow periodic testing.
- **Fuel Oil Day Tanks** – Each standby diesel generator is provided with an individual immediate-use fuel oil day tank supplied from the common fuel oil storage tank via individual supply lines and transfer pumps. Both tanks are located in individual diked areas of the Standby Diesel Generator Building near their associated diesel generators. Each day tank is sized for the maximum allowable (660 gal [2,500 L]) in accordance with NFPA 37 Section 5-3.2.

11.9.1.10 Instrument Air System

11.9.1.10.1 Function

The functions of the Instrument Air System include the following:

Supply instrument quality air (as defined by ANSI/ISA-S7.0.01-1996, "Quality Standard for Instrument Air) or better for the following:

- Instrument air (-40°C) with buffer storage for air-operated valves and HVAC dampers
- Ventilation and cooling air for gloveboxes and the pelletizing press bellows
- Normal bubbling / scavenging air for level measurement and hydrogen dilution during normal operation
- Independent emergency scavenging air for plutonium vessels to prevent radiolysis-related hydrogen buildup following an earthquake, loss of normal instrument air, or loss of power
- Super dry -80°C at 1 bar (-112°F at 14.5 psia) process air for ventilation and cooling of the AP powder gloveboxes
- Nitrogen System backup supply for glovebox scavenging.

The "Scavenging Air System" is subsystem of the Instrument Air System. The term "scavenging air" as used here is for air performing a "purge" or "dilution" of any radiolysis generated hydrogen in a vessel vapor space and not a chemical reaction (such as excess hydrogen scavenging or combining with free oxygen). During normal operation, the Instrument Air System (-40°C dew point) provides scavenging air to the Process vessels requiring scavenging air. During an emergency or loss of Instrument Air, the Emergency Scavenging Air subsystem provides the scavenging air function to all vessels containing Pu that are undergoing radiolysis to form hydrogen. Each train of Scavenging Air contains sufficient air to maintain the hydrogen concentration in the vapor spaces of supplied vessels ≤ 1% Hydrogen for seven days.

The Emergency Scavenging Air System is the portion of the Instrument Air System that is identified as a principal SSC. The Emergency Scavenging Air System supplies air to vessels containing plutonium to prevent radiolysis-related hydrogen buildup following a seismic event, loss of normal instrument air, or loss of power. See section 11.9.5 for a description of the design basis for this system.

Instrument and process air is produced by passing service air through air dryers prior to being stored in an instrument air receiver tank. The instrument air will have a dew point equal to, or lower than, -40°F (-40°C). The capacity of the instrument air receiver tank will be based on operation of selected equipment in the event of a loss of power to the compressors. Distribution piping supplies compressed air at a steady pressure to the required services within the facility. The design of the instrument air system and the structures, systems and components that rely on the instrument air system take into account lessons learned from industry experience (such as

NRC IN letters 95-53, 92-67, 88-24, 88-43 and 87-28). A portion of the -40°F (-40°C) instrument air will be dried further to obtain super dry process air with a dew point of less than -80°C. The super dry process air is used for various instruments and for all air being supplied directly to the process stream in the AP Area. The air is also used for glovebox applications.

11.9.1.10.2 Description

The Instrument Air System receives air supplied by the Service Air System at 7 bars (101.5 psia) and dries and filters it to a dew point of -40°C at 1 bar (-40°F at 14.5 psia) and 1 μ, respectively, for instrument and process functions. Instrument air is further dried to a dew point of -80°C at 1 bar (-112°F at 14.5 psia) and supplied at up to 4 bars (58 psia) and 1 μ filtration for scavenging AP gloveboxes and miscellaneous equipment, such as air lift pumps used for vessel mixing and material transport and to the air ejectors used for vessel vapor space evacuation.

The bubbling air that is used for level measurement in vessels also provides normal scavenging air to vessels containing compounds that undergo radiolysis to form hydrogen. If the normal bubbling air is lost, an Emergency Scavenging Air System is used. Although the Emergency Scavenging Air System is used to replace the normal scavenging air supply, it is not physically connected to the normal scavenging air supply (i.e., it has a separate nozzle to supply the vessel/tank).

An emergency seven-day supply of scavenging air for vessels requiring scavenging is supplied by redundant banks of compressed air cylinders, separate from the normal instrument air supply. Seven days is considered a reasonable period for restoration of the normal bubbling air supply for use in vessel scavenging following failure of the instrument air system. The emergency scavenging air system provides air to prevent radiolysis-related hydrogen buildup following a loss of the normal air supply.

The receiver buffer tanks provide air to facilitate a normal process shutdown following loss of the instrument air system.

The emergency scavenging air supply is automatically activated following a loss of the normal instrument air supply by opening one of two parallel, fail open, air operated valves. When the emergency scavenging air supply is in operation, the scavenging air header supply valve is automatically switched to the backup bank of cylinders upon low pressure at the outlet of the operating bank of cylinders. HEPA filters are provided in gas lines penetrating primary and secondary confinements, and the emergency scavenging air supply is seismically designed. Figure 11.9-10 provides a schematic of the Instrument Air System.

11.9.1.10.3 Major Components

The major components of the Instrument Air System are as follows:

- **Filters** – Particulates greater than 25 μ will be removed from miscellaneous service air and greater than 1 μ for column pulsation and instrument air.

- **Breathing Air Purifier** – The purifier is used to remove mists, water, carbon monoxide, and all particulates larger than 0.01 μm. The resulting breathing air will have a dew point of +40°F or less at 14.5 psig.
- **Receivers** – Buffer tanks for the MP and AP Areas store pressurized breathing air.

11.9.1.11.4 Control Concepts

The control concepts for the Breathing Air System are as follows:

- **Breathing Air Compressor Operation and Load Control** – The compressors are placed in service and loaded, as needed, by automatic load controllers sensing header and receiver pressure.

11.9.1.11.4.1 System Interfaces

The Breathing Air System does not connect to any other systems. It interfaces with the Normal and Standby Power Supplies.

11.9.1.12 Vacuum Radiation Monitoring System

11.9.1.12.1 Function

The function of the Vacuum Radiation Monitoring System is to provide the motive force to draw air from each enclosed, monitored space through its associated continuous air monitor detector assembly and to exhaust it into the High Depressurization Exhaust System via a common vacuum header and pumps.

11.9.1.12.2 Description

The Vacuum Radiation Monitoring System consists of a common vacuum header and associated piping connected to the outlet of parallel continuous air monitors and samplers designed to sample and evaluate airborne radioactivity throughout the MOX Fuel Fabrication Building. It will also provide vacuum for an additional 10% to 15% connection points for portable monitors and air samplers. The motive force (vacuum) is provided by multiple, parallel vacuum pumps in continuous service with at least one spare. The vacuum pumps discharge into the High Depressurization Exhaust System. The system is sized to provide vacuum based on airflow requirements.

Figure 11.9-12 provides a schematic of the Vacuum Radiation Monitoring System.

11.9.1.12.3 Major Components

The major components of the Vacuum Radiation Monitoring System are as follows:

- **Vacuum Pumps** – The system utilizes multiple, parallel full-capacity vacuum pumps with a design margin to achieve the required vacuum and airflow conditions.

- **Bypass Valve** – To allow precise vacuum control and to let the pumps operate near optimum efficiency, makeup flow is provided to the pump suction. The bypass valve for makeup flow is controlled by suction header pressure.

11.9.1.12.4 Control Concepts

The primary control requirement for the Vacuum Radiation Monitoring System is to control the vacuum header pressure and allow the pump to operate at or near its optimum efficiency point. To achieve this, makeup flow is provided to the pump suction. The bypass valve for makeup flow is controlled by suction header pressure.

11.9.1.12.5 System Interfaces

The Vacuum Radiation Monitoring System interfaces with the continuous air monitors and air samplers, High Depressurization Exhaust System, and normal and standby power supplies.

11.9.2 Bulk Gas Systems

The Bulk Gas Systems within the MOX Fuel Fabrication Building are as follows:

- Nitrogen System
- Argon/Hydrogen System
- Helium System
- Methane/Argon System
- Oxygen System.

There are no bulk gas systems with a safety function, thus none are designated as a PSSC. See Chapter 5 for additional information regarding the designation of PSSC.

11.9.2.1 Nitrogen System

11.9.2.1.1 Function

The Nitrogen System normally supplies gaseous nitrogen for the following:

- Once-through ventilation of gloveboxes
- Atmosphere changes for the sintering furnace airlocks
- Scavenging of the calcination furnace bearings (to extend the life of the bearings)
- Hydrazine and hydroxylamine nitrate tanks
- Other miscellaneous process users.

The system also provides gaseous nitrogen as the backup supply for dried instrument air ventilation of gloveboxes, equipment, and the pelletizing press bellows. In addition, nitrogen serves as a third backup for the sintering furnace in the event that the furnace loses its main argon/hydrogen supply, its backup supply (argon/hydrogen mixed gas cylinders), and its secondary backup supply (argon supply).

The power for the GMA System controls and monitoring is provided from a 120-volt UPS utilities panel. The seismic isolation valves are also powered by 120-volt UPS utilities panel.

Instrument Air Supply (IAS)

The Instrument Air System supplies motive air to the GMA air-operated valves. For each GMA AOV, the GMA to IAS boundary is air inlet side of the first root valve upstream of the air operator.

11.9.3 Reagent Systems

The Reagent Systems within the MOX Fuel Fabrication Building are as follows:

- Nitric Acid System
- Silver Nitrate System
- Tributyl Phosphate System
- Hydroxylamine Nitrate System
- Sodium Hydroxide System
- Oxalic Acid System
- Diluent System
- Sodium Carbonate System
- Hydrogen Peroxide System
- Hydrazine System
- Manganese Nitrate System
- Decontamination System
- Nitrogen Oxide System.
- Aluminum Nitrate System
- Zirconium Nitrate System
- Uranyl Nitrate System

There are no safety functions associated with reagent systems, thus none are designated as a PSSC. See chapter 5 for additional information regarding the designation of PSSCs.

11.9.3.1 Nitric Acid System

11.9.3.1.1 Function

The Nitric Acid System provides nitric acid to the AP process for the following:

- Dissolving PuO_2 in the Dissolution Unit and Dechlorination Dissolution Unit
- Plutonium stripping and acid scrubbing in the Purification Cycle
- Acidification in the Solvent Recovery Cycle and Oxalic Precipitation and Oxidation Unit
- Oxalic mother liquor adjustment in the Oxalic Precipitation and Oxidation Unit
- Oxalic mother liquor concentration in the Oxalic Mother Liquor Recovery Unit.

The Nitric Acid System also provides nitric acid for the preparation of hydrazine, oxalic acid, manganese nitrate, uranium nitrate, decontamination solution, zirconium nitrate, and silver nitrate reagents.

11.9.3.1.2 Description

The 13.6N nitric acid is stored in totes in the Reagent Processing Building. It is transferred into the 13.6N fresh nitric acid storage tank in the Reagent Processing Building and then pumped into the fresh acid break pot to supply Hydrazine System users in the Reagent Processing Building. Nitric acid is also pumped to a 13.6N fresh nitric acid storage tank in the AP Area to supply users in that area. In the Reagent Processing Building a nitric acid drain tank is used to capture spills and drains from the 13.6N fresh nitric acid storage tank and transfer pumps in the Reagent Processing Building. Nitric acid is pumped from the 13.6N fresh nitric acid storage tank in the AP area to two break pots: one to supply process users (6N nitric acid preparation tank) and the other to supply preparation tanks for 1.5N nitric acid, 0.05M oxalic acid, manganese nitrate, and silver nitrate.

The 6N nitric acid is prepared in a tank in the AP Area by mixing 13.6N nitric acid with demineralized water. The tank is pressurized with compressed air. During normal operation of the AP process, the use of high pressure 6 N nitric acid is not required as the nitric acid is fed to the electrolyzers from atmospheric tanks by gravity. However, if one of the electrolyzers in the Dissolution or Dechlorination Dissolution units must be emptied for maintenance or repair (a very exceptional condition), the contents are temporarily manually transferred to the corresponding downstream geometrically safe slab tank, bypassing the filter that usually removes minute amounts of undissolved PuO_2. If the liquid were processed through the filter to remove the particulates, the undissolved PuO_2 particulates in the liquid could blind the filter and make the transfer impossible.

The electrolyzer is designed and tested to prevent settling out of the particulates as they are dissolved; however, the slab tank is unable to maintain the particulates in suspension because of its required geometry and lack of mixing equipment. As a result, when the solution is returned back to the electrolyzer, many particulates may remain as residue in the bottom and on the sides of the slab tank. These must be resuspended in the smallest volume possible and transferred back to the electrolyzer so that the particulate PuO_2 can be redissolved through normal process at the electrolyzer.

Resuspending the particulate PuO_2 requires the use of pressurized nitric acid to dislodge the particulates from the walls and bottom of the slab tank. Compressed air will be used to supply nitric acid from a dedicated nitric acid pot (see Figure 11.9-33). The pot and all connecting components will be designed for the 7 barg (100 psig) pressure condition, safely isolating the rest of the nitric acid system from the high pressure. The piping is rated for 150 psig.

During the resuspensioning stage, the 100 psig nitric acid would be introduced into the tank in small amounts until, after two or three cycles of rinsing, the particulates are resuspended and returned to the electrolyzer. The wash volume is restricted to the volume of the electrolyzer.

The slab tank is unaffected by the pressure of the nitric acid as the pressure drops to system pressure (-2" W.C.) immediately on exiting from the inlet nozzle. The tank is vented directly to the offgas system that is maintained at an even more negative pressure. Thus, the only part of the system affected by the high pressure is the standby tank, the isolation valves, and piping.

the draft on the suction side of the water jet venturi. Once set, the draft will remain stable since the vents are static (no flow from the vents).

- **Gas Stripping Column for AP Area-** This packed self regulating column operates continuously. Fresh demineralized water is used to scrub the entering vapors via flow control. The flow is sufficient to cause the recirculating scrubber water to overflow the column continuously to the Liquid Waste Reception Unit. Draft in the column is controlled by manually adjusting a regulating butterfly valve which introduces outside air into the column suction intake. Scrubber vapors exiting the column are demisted, pass through two sets of filters in series for filtration prior to entering two exhaust fans which provide the motive force to draw the vapors through the column. A manual balancing butterfly valve redirects some of the fan exhaust to the intake to modulate the fan flow capacity.
- **MOX Fuel Fabrication Building Isolation** – The nitric acid penetrations into the MOX Fuel Fabrication Building are provided with double isolating valves to automatically isolate during a seismic event.

11.9.3.1.5 System Interfaces

The Nitric Acid System interfaces with the following:

- Normal Power Supply
- Standby Power Supply
- Seismic detectors, which provide a signal to automatically isolate fluid penetrations into the MOX Fuel Fabrication Building during a seismic event.

The AP process interfaces for the Nitric Acid System include the following:

- Dissolution Unit
- Dechlorination Dissolution Unit
- Purification Cycle
- Oxalic Precipitation and Oxidation Unit
- Acid Recovery Unit
- Solvent Recovery Cycle
- Oxalic Mother Liquor Recovery Unit
- Liquid Waste Reception Unit
- Uranium Dissolution
- Off Gas Treatment.

The Reagent System interfaces for the Nitric Acid System include the following:

- Oxalic Acid System

- Manganese Nitrate System
- Silver Nitrate System
- Demineralized Water System
- Decontamination system
- Sodium Carbonate
- Sodium Hydroxide
- Hydroxylamine Nitrate
- Diluent
- Hydrazine
- Aluminum Nitrate
- Zirconium Nitrate
- Uranyl Nitrate.

11.9.3.2 Silver Nitrate System

11.9.3.2.1 Function

The Silver Nitrate System provides silver nitrate to the electrolyzers in the Dechlorination Dissolution and Dissolution Unit.

11.9.3.2.2 Description

A prepared 10N silver nitrate solution is added to demineralized water and 13.6N nitric acid in a preparation tank in the AP Area and is then mixed for homogeneity. After sampling to assure solution strength, the solution is fed to process users by a dosing pump.

Figure 11.9-18 provides a schematic of the Silver Nitrate System.

11.9.3.2.3 Major Components

The major components of the Silver Nitrate System are the silver nitrate preparation tank and the silver nitrate pump, both located within the AP Area. The material of construction for all wettable surfaces is Type 304L stainless steel for corrosion resistance.

11.9.3.2.4 Control Concepts

The control concepts for the Silver Nitrate System are as follows:

- The operator in the control room verifies the level of fluid in the silver nitrate preparation tank.
- The operator in the control room issues a command to open the water inlet valve to add a preset quantity of demineralized water into the silver nitrate preparation tank. When the required amount of demineralized water has been added, the demineralized water inlet

hydroxylamine nitrate preparation tank in the Reagent Processing Building. Hydroxylamine nitrate from the 1.9M buffer tank is supplied to the Purification Cycle users.

In the 0.15M hydroxylamine nitrate preparation tank, the 1.9M hydroxylamine nitrate is mixed with 13.6N nitric acid, 4M hydrazine nitrate, 1M nitric acid, and demineralized water to form a solution of 0.15M hydroxylamine nitrate, 0.14M hydrazine nitrate, and 0.1N nitric acid. The 0.15M hydroxylamine nitrate solution is pumped by the 0.15M hydroxylamine nitrate transfer pumps to the 0.15M hydroxylamine nitrate buffer tank in the AP Area. The 0.15M hydroxylamine nitrate distribution pumps supply the solution to a break pot from where it is supplied to the Purification Cycle users.

Figure 11.9-20 provides a schematic of the Hydroxylamine Nitrate System.

11.9.3.4.3 Major Components

The major components of the Hydroxylamine Nitrate System are the 1.9M hydroxylamine nitrate storage tank, 1.9M hydroxylamine nitrate buffer tank, 0.15M hydroxylamine nitrate preparation tank, 0.15M hydroxylamine nitrate buffer tank, hydroxylamine nitrate stripping column, hydrazine and HAN effluents storage tank, and 0.15M hydroxylamine nitrate distribution pumps.

11.9.3.4.4 Control Concepts

The control concepts for the Hydroxylamine Nitrate System are as follows:

- **1.9M Hydroxylamine Nitrate Storage Tank** – A low level in this tank stops the 1.9M hydroxylamine nitrate pumps. A high level stops the HAN drum pump from overfilling the tank. A nitrogen purge is provided under flow control. The tank vents to hydrazine column CLMN1000.
- **1.9M Hydroxylamine Nitrate Buffer Tank** – The totalizer control valve feeding the buffer tank is closed on volumetric batch control. The HAN pump feeding the tank is stopped on high tank level.
- **0.15M Hydroxylamine Nitrate Preparation Tank** – When the 0.15M hydroxylamine nitrate preparation tank reaches low level, the 0.15M hydroxylamine nitrate transfer pumps are stopped and the control room operator is notified. The demineralized water valves are opened, and a predetermined amount of demineralized water is added to the tank. After the water valve is fully closed, a preset quantity of 1.9M hydroxylamine nitrate is added. After the 1.9M hydroxylamine nitrate valve is fully closed, hydrazine nitrate is added. After the hydrazine nitrate valve closes, nitric acid is added. The operator checks the level and takes a sample for laboratory analysis. If the sample is found to be satisfactory, the operator then notifies the control room operator, who validates the "tank ready" signal. The 0.15M hydroxylamine nitrate is then pumped to users.
- **0.15M Hydroxylamine Nitrate Buffer Tank** – A high level in the buffer tank closes the 0.15M hydroxylamine nitrate feed valve to prevent overfilling the tank. A low level in this tank stops the 0.15M hydroxylamine nitrate distribution pumps. A nitrogen purge is provided under flow control. The tank vents to hydroxylamine nitrate stripping column.

- **Hydroxylamine Nitrate Stripping Column** – Circulating fluid is provided for scrubbing the vents from the 0.15 hydroxlamine buffer tank, the 1.9M HAN buffer tank, and the HAN drain tank. The tower is fed with a 5% hydrogen peroxide fresh makeup from a bottle. The vents are drawn through the column via the HAN stripping column fan under manual butterfly valve draft control. The column blowdown is periodically routed to the HAN drain tank.

- **HAN Drain Tank** – The drain tank is used to store the Hydroxyl Amine Stripping Column blowdown before being pumped to drums for disposal. The HAN tank vents to the Hydroxyl Amine Stripping Column. This tank is located in the Aqueous Polishing building.

- **Hydrazine and HAN Effluents Storage Tank** – The hydrazine and HAN effluents storage tank is used to collect all of the drip tray collected drips, piping low point drains, and any equipment overflows that may occur from the HAN and hydrazine tanks, pumps, piping, and vessels located in the Reagents building. A tank high level alarm notifies the local operator that the tank is full. The tank is emptied to a lorry for disposal via the hydrazine and HAN drain pump. A rinsing solution (composition to be determined) is used to rinse the drip trays, piping and hydrazine and HAN effluents storage tank after use.

- **MOX Fuel Fabrication Building Isolation** – The hydroxylamine nitrate fluid penetrations into the MOX Fuel Fabrication Building are provided with double isolating valves to automatically isolate during a seismic event.

11.9.3.4.5 System Interfaces

The Hydroxylamine Nitrate System interfaces with the following:

- Purification Cycle
- Nitrogen system
- Nitric acid system
- Demineralized water system
- Hydrazine system
- Normal and Standby Power Supply
- Seismic detectors, which provide a signal to automatically isolate the hydroxylamine nitrate fluid penetrations into and out of the MOX Fuel Fabrication Building during a seismic event.

11.9.3.5 Sodium Hydroxide System

11.9.3.5.1 Function

The Sodium Hydroxide System provides 10N sodium hydroxide for mixing with hydrazine, for pH control Liquid Waste Reception Unit, for scrubbing liquor in the Dechlorination Dissolution Unit, and 0.1N sodium hydroxide for Solvent Recovery Unit washing.

11.9.3.5.2 Description

Sodium hydroxide is stored in a tote tank in the Reagent Processing Building at a concentration 10N. It is pumped to the 10N Sodium Hydroxide Preparation tank. From the 10N Preparation tank it is pumped to the Hydrazine System, Liquid Waste Reception Unit, and the 0.1N Sodium Hydroxide Preparation Tank. In the 0.1N Sodium Hydroxide Preparation Tank, sodium hydroxide is mixed with demineralized water to prepare 0.1N solution. This tank is equipped with a mixer. The 0.1N solution is then transferred to the distribution tank and pumped to a break pot where it is fed to the Solvent Recovery Cycle.

All vessels in the Sodium Hydroxide System are made of 304 stainless steel.

Figure 11.9-21 provides a schematic of the Sodium Hydroxide System.

11.9.3.5.3 Major Components

The major components of the Sodium Hydroxide System are the 10N sodium hydroxide preparation tank, which is located in the Reagents Process building, the 0.1N sodium hydroxide preparation tank, and the 0.1N sodium hydroxide distribution tank, both are located within the AP Area.

11.9.3.5.4 Control Concepts

The control concepts for the Sodium Hydroxide System are as follows:

- **10 N Sodium Hydroxide Preparation Tank** – When the 10N sodium hydroxide preparation tank is nearly empty, the control room operator is warned and manually pumps 10N sodium hydroxide solution from totes to the 10N NaOH Preparation Tank via a drum pump. The drum pump stops on tank high level. On low low level in the 10N NaOH Preparation Tank, the transfer of 10N NaOH stops to the 0.1N NaOH Preparation Tank, the Hydrazine System Tank, and the Liquid Waste Treatment tanks.
- **0.1N Sodium Hydroxide Preparation Tank** – When the 0.1N Sodium Hydroxide Preparation Tank reaches a low level, the draw-off valve on the outlet closes and the control room operator is warned. The operator in the control room issues a command to open the water inlet valve to add a preset quantity of demineralized water into the sodium hydroxide preparation tank. When the required amount of demineralized water has been added, the demineralized water inlet valve is closed. After the demineralized water inlet valve is fully closed, the 10N sodium hydroxide solution control valve is opened and the sodium hydroxide is added. The operator then starts the mixer. After the preset time

necessary for homogeneity has elapsed, the mixer stops and a "tank ready for sampling" message is sent to the control room and the local control station. The local operator then takes a sample and sends it to the laboratory for analysis.

If the results of analysis of the sample are found to be correct, the control room operator validates the "tank ready" signal, which allows the operation of the sodium hydroxide transfer pump to transfer from the 0.1N NaOH Preparation Tank to the 0.1N Distribution Tank. A low-low level in 0.1N NaOH Preparation tank stops the transfer.

- **0.1N Distribution Tank** – when the 0.1N NaOH Distribution Tank reaches high level the 0.1N NaOH transfer valve is closed. On low low level the 0.1N distribution pump stops.
- **MOX Fuel Fabrication Building Isolation** – The fluid penetrations into the MOX Fuel Fabrication Building are provided with double isolation valves to automatically isolate during a seismic event.

11.9.3.5.5 System Interfaces

The Sodium Hydroxide System interfaces with the following:

- Hydrazine System (RHZ)
- Nitric Acid System (RNA)
- Sodium Carbonate System (RSC)
- Solvent Recovery Unit (KPB)
- Liquid Waste Reception Unit (KWD)
- Demineralized Water System (DMW)
- Normal and Standby Power Supply
- Service Air System (SAS)
- Seismic detectors, which provide a signal to automatically isolate the sodium hydroxide fluid penetrations into the MOX Fuel Fabrication Building during a seismic event.

11.9.3.6 Oxalic Acid System

11.9.3.6.1 Function

The Oxalic Acid System provides oxalic acid for converting plutonium nitrate to plutonium oxalate in the Oxalic Precipitation and Oxidation Unit.

11.9.3.6.2 Description

Solid oxalic acid is stored in bags in the Reagent Processing Building. The bags are fed to a bag-opening feeder provided with a vibrator that is coupled with the preparation tank. The

- The operator then adds concentrated manganese nitrate solution to the vessel. The operator monitors the level in the preparation tank and stops manganese nitrate addition when the appropriate quantity has been added. The operator starts the preparation tank stirrer that runs for a preset duration and then stops. The tank is sampled to verify that the desired material concentration has been prepared. When the sample is verified correct, the operator validates a "tank ready" signal, which disables the stirrer and opens the feed to the buffer pot.

11.9.3.11.5 System Interfaces

The Manganese Nitrate System interfaces with the following:

- Nitric Acid System
- Oxalic Precipitation and Oxidation Unit
- Normal and Standby Power Supply.

11.9.3.12 Decontamination System

11.9.3.12.1 Function

The Decontamination System supplies a nitric acid solution for the decontamination of process equipment in the AP process.

11.9.3.12.2 Description

The decontamination solution is prepared by mixing 13.6N nitric acid and demineralized water in the decontamination solution tank in the AP Area. The decontamination solution is pumped by transfer pumps to supply the process users. For ease of distribution, some gloveboxes may be fed from local buffer vessels installed above the gloveboxes.

Figure 11.9-28 provides a schematic of the Decontamination System.

11.9.3.12.3 Major Components

The major components of the Decontamination System are as follows:

- Decontamination solution preparation tank
- Transfer pumps

11.9.3.12.4 Control Concepts

The control concepts for the Decontamination System are as follows:

- **Decontamination Solution Preparation Tank** – The demineralized water and nitric acid valves are closed on high level. On low level, the transfer pumps are shut down and the mixer is stopped. The tank is protected with an overflow to Acid Recovery Unit Tank and is vented to the Nitric Acid Unit gas stripping column.

- **MOX Fuel Fabrication Building Isolation** – The decontamination fluid penetrations into the MOX Fuel Fabrication Building are provided with double isolation valves to automatically isolate during a seismic event.

11.9.3.12.5 System Interfaces

The Decontamination System interfaces with the following:

- Dissolution Unit
- Dechlorination Dissolution Unit
- Purification Cycle
- Solvent Recovery Unit
- Homogenization Unit
- Oxalic Mother Liquor Recovery Unit
- Oxalic Precipitation and Oxidation Unit
- Uranyl Nitrate System
- Acid Recovery Unit
- Nitric Acid System
- Demineralized Water System
- Liquid Waste Reception Unit
- Offgas Treatment Unit
- Normal and Standby Power Supply
- Seismic detectors, which provide a signal to automatically isolate the fluid penetrations into the MOX Fuel Fabrication Building during a seismic event.

11.9.3.13 Nitrogen Oxide System

11.9.3.13.1 Function

The Nitrogen Oxide System provides nitrous fumes (nitrogen dioxide + nitrogen tetroxide) for the AP process to remove hydrazine and hydroxylamine nitrate from the plutonium nitrate stream via an oxidation reaction in the Purification Cycle.

11.9.3.13.2 Description

Dinitrogen tetroxide (N_2O_4) liquid is stored in two 1-ton cylinders. One cylinder is in operation, and the second cylinder is a spare. Instrument air is injected into the cylinder to transfer the liquid into an electric boiler where it is vaporized.

The vapor is mixed with instrument air and heated by electric tracing to 122°F (50°C) to avoid problems associated with condensation of NO_x from the boiler.

11.9.3.15 Zirconium Nitrate System

11.9.3.15.1 Function

Zirconium nitrate is added to the process to avoid fluoride corrosion of titanium vessels in the Purification Cycle and Acid Recovery unit by complexing the fluoride with zirconium.

11.9.3.15.2 Description

The zirconium nitrate solution is pump from drums to a zirconium preparation tank where the zirconium nitrate is prepared as a 10 g/l zirconium concentration in a 3.5 N nitric acid solution. The tank is a nominal 40 gallon tank located in the Reagents Processing Building. The tank includes a stirrer and sampling nozzles to confirm concentrations. The solution is then pumped to a 40 gallon zirconium nitrate buffer tank in the Aqueous Polishing Building. Usage of zirconium nitrate solution is about 30 gallons per week..

The zirconium solution is supplied to the KPA raffinates TK9000 and to the KPC system where it is further in line diluted with demineralized water to form a very dilute (150 mg/l) solution that is fed to the Acid Recovery Unit evaporator EV2000.

11.9.3.15.3 Major Components

The major components of the Zirconium Nitrate System are as follows:

- Zirconium Nitrate Preparation Tank
- Zirconium Nitrate Buffer Tank
- Zirconium Nitrate Transfer Pump

11.9.3.15.4 Control Concepts

The control concepts for the Zirconium Nitrate System are as follows:

- The zirconium nitrate buffer tank is equipped with a low-level alarm to alert the operator to prepare a new batch. The dosing pump is turned off on low-low level in this tank.
- The zirconium nitrate buffer tank is equipped with a low-level switch, which starts the transfer pump to fill up this tank. A high level in this tank stops the transfer pump.
- Zirconium nitrate/nitric acid solutions may be available in drums in a 20 wt% solution zirconium in nitric acid concentration or available in 10g/l zirconium that will require no further adjustment. The following concept is based on the 20 wt% solution zirconium in nitric acid but may change as the availability of the reagent becomes clear.
- When the level in the zirconium nitrate preparation tank is low, the control valve at the outlet of the tank is closed and the control room operator is notified. The control room operator issues a command to open the demineralized water valve. After a preset amount of demineralized water is added to the tank, the valve closes. The nitric acid valve opens

after the demineralized valve is fully closed. A preset amount of acid is added. The acid addition valve closes and a preset amount of zirconium nitrate solution is pumped to the preparation tank. The mixer is on during this operation. The local operator takes a sample from the tank and sends it to the laboratory for analysis. If the results of sample analysis are found to be correct, the local operator notifies the control room operator. The control room operator then allows the automation process to continue to send the zirconium nitrate solution to users.

- MOX Fuel Fabrication Building Isolation – The zirconium nitrate penetrations into the MOX Fuel Fabrication Building are provided with double isolation valves to automatically isolate during a seismic event.

11.9.3.15.5 System Interfaces

The major components of the Zirconium Nitrate System are as follows:

- Normal and standby Power Supply
- Demineralized Water System
- Acid Recovery
- Nitric Acid System
- Purification Cycle
- Seismic detectors, which provide a signal to automatically isolate the fluid system penetrations into the MOX Fuel Fabrication Building during a seismic event

11.9.3.16 Uranyl Nitrate System

11.9.3.16.1 Function

The Uranyl Nitrate System provides depleted uranyl nitrate to reduce the isotopic composition of uranium in the plutonium feed stream and the uranium waste stream. The isotopic dilution is performed with depleted uranium at 0.25% U-235 in 1N Nitric Acid solution.

11.9.3.16.2 Description

Uranyl nitrate solution is stored in drums in the MOX Secured Warehouse. Drums are brought by truck to the Aqueous Polishing Building. Each drum is identified, weighed, sampled, and opened manually. Uranyl nitrate solution is pumped from a drum to a preparation tank where the solution is again tested. Nitric acid and demineralized water is available for adjustments. From the preparation tank, the solution is pumped by transfer pump to a distribution tank, all in the Aqueous Polishing Building. The uranyl nitrate distribution pumps deliver the solution to a break pot where it is supplied to the Dissolution Unit, the Dechlorination and Dissolution Unit, and the Purification Cycle.

Figure 11.9-34 provides a schematic of the Uranyl Nitrate System.

11.9.3.16.3 Major Components

The major components of the Uranyl Nitrate System are as follows:

- Drum Pump
- Preparation Tank
- Transfer pump
- Distribution tank
- Distribution pumps
- Break pot

11.9.3.16.4 Control Concepts

The control concepts for the Uranyl Nitrate System are as follows:

- **Uranyl Preparation Tank** – A low-low level in this tank alerts the control room operator and stops the transfer pump. An operator will manually initiate the drum pump to pump the solution to the preparation tank. The drum pump stops on high tank level or when the preset weight of the drum is reached on the scale. The tank level is monitored at the drum station. The local operator checks the level and takes a sample. If the results of analysis of the sample are found to be correct, the operator in the control room validates the "tank ready for distribution" signal, which allows the transfer pump to pump uranyl nitrate to the distribution tank. The preparation tank has two independent level transmitters associated with IROFS sampling, and if the tank level changes while waiting for the solution to transfer, the control room receives a "tank not ready for distribution" signal. The preparation tank is equipped with an agitator to enhance mixing. The tank contains a decontamination solution connection for rinsing.
- **Uranyl Nitrate Distribution Tank** – A low level in the distribution tank starts the transfer pumps to fill this tank. A high level in the distribution tank stops the transfer pumps to prevent overfilling. After a sufficient amount is transferred, the transfer pump is stopped. A low-low level in the distribution tank stops the distribution pumps. The level is monitored in the control room. The tank contains a decontamination solution connection for rinsing.
- **Uranyl Nitrate Break Pot** – The break pot receives uranyl nitrate from the distribution pumps and supplies end users. The overflow gravity flows to the distribution tank.

11.9.3.16.5 System Interfaces

The Uranyl Nitrate System interfaces with the following:

- Nitric Acid System
- Demineralized Water System
- Dechlorination Dissolution and Dissolution Units
- Purification Unit
- Normal Power Supply
- Decontamination System

11.9.4 Design Basis for Non-Principal SSCs

The design basis for non-principal SSCs is a combination of implementation of the design basis parameters provided in Table 11.8-2, FTS Categories 3 and 4 and the codes and standards which are applicable to components in the Mechanical Utility Systems, Bulk Gas Systems, and Reagent Systems.

The following codes and standards will be used in the design of non-principal SSCs

<u>Vessels</u>

- ASME VIII, "Boiler and Pressure Vessel Code, Rules for Construction of Pressure Vessels"
- UL 142, "Steel Aboveground Tanks for Flammable and Combustible Liquids"
- API RP 520, "Sizing, Selection and Installation of Pressure Relieving Devices in Refineries"
- API RP 521, "Guide for Pressure Relieving and Depressurizing Systems."

Pumps

- ANSI /ASME B73.1M, "Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process."

Piping

- ANSI/ASME B31.3, "Process Piping."

Storage Tanks (0-15 psig)

- API 620 (1998), "Design & Construction of Large, Welded, Low Pressure Storage Tanks."

Gases

- CGA G-4, "Oxygen"
- CGA G-5, "Hydrogen"
- CGA G-7, "Compressed Air for Human Respiration"
- CGA G-9 (1998), "Helium"
- CGA G-10 (1997), "Nitrogen"
- CGA G-11 (1998), "Argon"
- CGA P-1, "Safe Handling of Compressed Gases in Containers"
- CGA P-9 (1992), "The Inert Gases Argon, Nitrogen, and Helium"
- CGA S-1.1, "Pressure Relief Device Standards – Part 1 – Cylinders for Compressed Gases"
- CGA S-1.3, "Pressure Relief Device Standards – Part 3 – Cargo and Portable Tanks for Compressed Gases"
- ANSI/ISA S7.0.01-1996, "Quality Standard for Instrument Air"
- NFPA 30, "Flammable and Combustible Liquids Code"
- NFPA 50, "Standard for Bulk Oxygen Systems at Consumer Sites"
- NFPA 50A, "Standard for Gaseous Hydrogen Systems at Consumer Sites"
- NFPA 55 (1998), "Standard for the Storage, Use and Handling of Compressed and Liquefied Gases in Portable Cylinders"
- NFPA 86C, "Standard for Industrial Furnaces Using a Special Processing Atmosphere."

Oxidizers

- NFPA 430, "Code for Storage of Liquid and Solid Oxidizers."

Diesel Generator Fuel Oil

- ANSI/ANS 59.51-1997, "American Nuclear Society Fuel Oil Systems for Safety Related Emergency Diesel Generators"
- API 620 (1998), "Design & Construction of Large, Welded, Low Pressure Storage Tanks"
- NFPA 30 (1996), "Flammable and Combustible Liquids Code"
- NFPA 37 (1998), "Standards for the Installation and Use of Stationary Combustion Engines and Gas Turbines"
- UL 142, "Steel Aboveground Tanks for Flammable and Combustible Liquids."
- NFPA 110, "Standard for Emergency and Standby Power Systems"

Seismic

Conventional seismic CS or SC-2 as applicable

11.9.5 Design Basis for Principal SSCs

The design basis for principal SSCs are as defined by design basis parameters listed in Table 11.8.2 and the design basis codes and standards as defined by FTS categories 1 and 2.

11.9.5.1 Scavenging Air

Normal Operation

Equipment containing high plutonium concentration solutions such as the electrolyzers, and tanks upstream and downstream from the Purification Cycle can generate hydrogen vapor via radiolysis. During normal operation, the Instrument Air System (-40°C dew point) provides scavenging air to keep the vessel vapor space hydrogen composition to less than or equal to 1.0 vol%.

Loss of Instrument Air

During an emergency or loss of normal Instrument Air, the Emergency Scavenging Air subsystem portion of the Instrument Air System fulfills the scavenging air function to those vessels that radiolysis hydrogen generation can produce enough hydrogen to reach more than 4 vol% hydrogen in the vessel's vapor space in seven days or less.

For the vessels that can reach more than 4 vol% hydrogen in seven days or less sufficient air is provided such that an explosive condition does not occur. The system consists of two independent trains. Each train of the emergency scavenging bottled air system contains sufficient air to dilute the hydrogen concentration in the vapor spaces of supplied vessels to ≤ 1% hydrogen

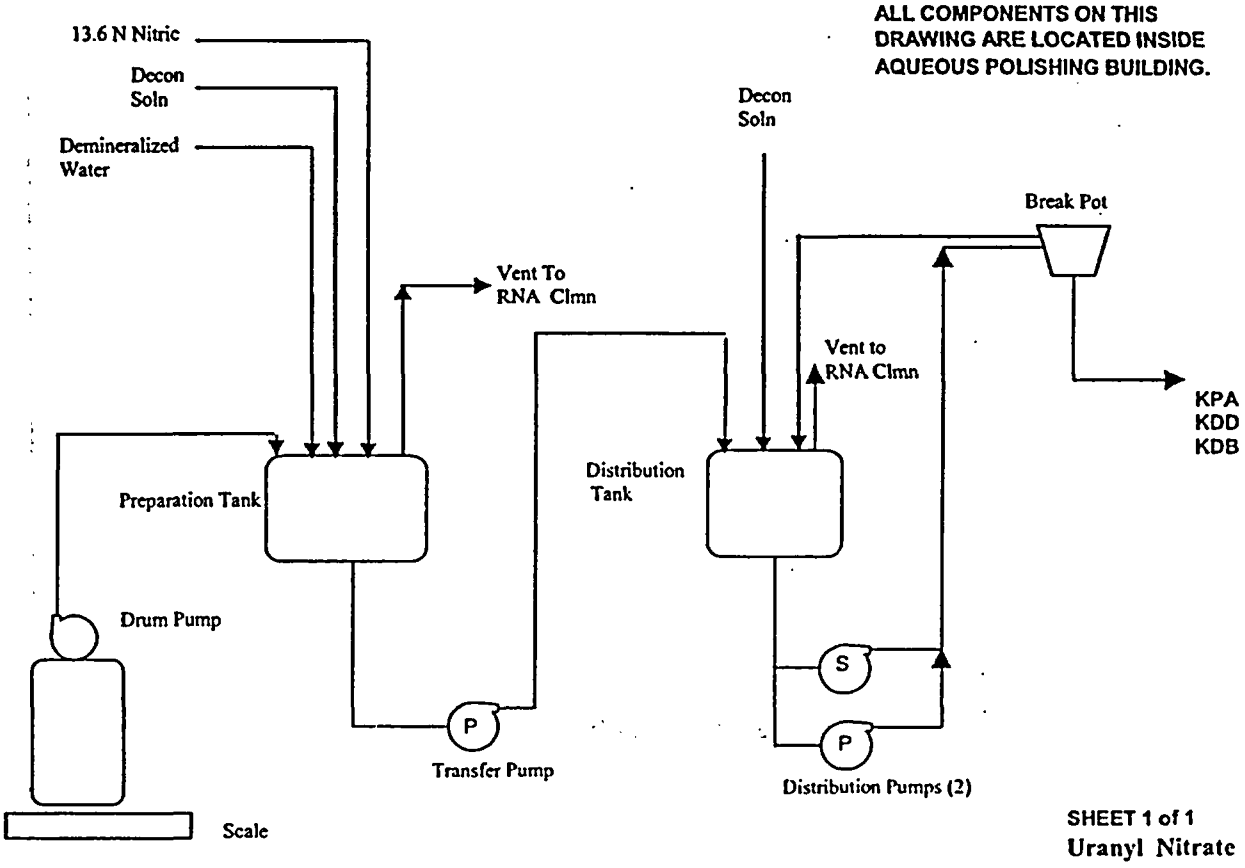

Figure 11.9-34. Uranyl Nitrate System

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11.10 HEAVY LIFT CRANES

Heavy lift cranes are defined as those overhead load handling systems in the MFFF that are designed to lift a load greater than the weight of a single fresh fuel assembly and associated lifting devices (i.e., greater than 1,800 lb [816 kg]), in accordance with NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants." The MFFF cranes that handle such loads are the bridge crane in the fresh fuel cask shipping truck bay (Room D-101), the bridge crane in the assembly loading area (Room B-183), the bridge crane in the fresh fuel cask handling area (Room B-185), the bridge crane (stacker) in the waste drum stacker area (Room B-254), the bridge crane in the PuO2 receiving area (Room B-163) and the maintenance hoist in the emergency generator building. Other cranes may be identified as the design progresses. Heavy lift cranes will be evaluated in the ISA and will have appropriate design and controls (see Section 11.10.7) to ensure consequences to workers, the IOC, or the environment are below the 10 CFR §70.61 limits.

Operating experience (i.e., lessons learned) from MELOX and La Hague will be incorporated as appropriate into the design and operations of heavy lift cranes used at the MFFF.

11.10.1 Function

Heavy lift cranes in the MFFF are designed to safely and reliably hoist critical or noncritical loads that weigh in excess of 1,800 lb (816 kg). Critical loads are defined as those loads whose uncontrolled movement or release could result in unacceptable radiological dose consequences to workers, the IOC, or the environment. Other loads are considered noncritical.

Heavy lift cranes that handle critical loads must retain their load during normal operation, design basis accidents (including a loss of electrical power), and design basis natural phenomena events. Heavy lift cranes that do not handle critical loads, but do travel over areas where safety or confinement systems are located and could cause consequences greater than 10 CFR §70.61 limits if the crane were to fall, must remain structurally integral under normal, accident, and design basis natural phenomena conditions.

11.10.2 Description

The bridge crane in the fresh fuel cask shipping truck bay (Room D-101) is designed to lift inbound or outbound material and equipment that is handled in the truck bay. Empty inbound fresh fuel shipping casks removed from shipping vehicles are stored in the truck bay until required for loading operations. Outbound casks loaded with fresh fuel may be staged in the truck bay awaiting shipment. Loaded fresh fuel shipping casks are normally handled in the truck bay on air pallets. However, in the event of a failure of the dock leveler height adjustment mechanism during the truck loading process, a cask could be lifted off of the dock leveler and moved to the loading dock by the truck bay bridge crane. The loaded cask would not be lifted over another loaded cask in this event. Any lift of a loaded fuel cask by the truck bay crane will be performed with appropriate impact limiters installed and with appropriate lift height limits (approximately 16 ft [4.9 m] above floor elevation) consistent with the qualification of the cask (30 ft [9.1 m] qualification height), which will mitigate the consequences of load drop accidents in the truck bay.

The bridge crane in the assembly loading area (Room B-183) is designed to transfer an empty fresh fuel cask strongback from the strongback handling station to the assembly loading station, to remove the strongback top plate to provide access for loading fuel assemblies, to replace the strongback top plate after three fuel assemblies are loaded, and to transfer the loaded strongback from the assembly loading station to the strongback handling station. All loaded strongback transfers will be performed with appropriate lift height limits, which will mitigate the consequences of load drop accidents in the assembly loading area. Generally, there will be only one loaded strongback; therefore, they are not lifted over other loaded strongbacks.

The bridge crane in the fresh fuel cask handling area (Room B-185) is designed to remove and replace the fresh fuel shipping cask impact limiters and cask lids. This crane is also designed to be used for other general maintenance purposes. Outbound casks loaded with fresh fuel may be staged in the cask handling area awaiting shipment. Loaded fresh fuel shipping casks are normally handled in the cask handling area on air pallets. However, in the event of a failure of an air pallet that required the cask to be lifted to withdraw the pallet, the cask could be lifted by the cask handling area crane. Any lift of a loaded fuel cask by the cask handling area crane will be performed with appropriate impact limiters installed and with appropriate lift height limits consistent with the qualification of the cask, which will mitigate the consequences of load drop accidents in the cask handling area.

The bridge crane (stacker) in the waste drum stacker area (Room B-254) is designed to transfer loaded pallets, each containing four waste drums, between the pallet conveyor and the pallet storage racks. When a waste drum is lifted, operators are aware of hazards of an event with the stacker allowing a drum to drop and would evacuate in the unlikely event of a waste drum being dropped. Consequences from a drop of a waste drum are below the 10 CFR §70.61 performance requirements to the site workers, the IOC and the environment and require no principal SSCs.

The bridge crane in the PuO2 receiving area (Room B-163) is designed to handle empty PuO_2 shipping package pallets. Because the empty PuO_2 shipping package pallets should be free of contamination (only minor amounts of contamination are permitted), dropping an empty pallet will not cause consequences that are in excess of 10 CFR §70.61 performance requirements to the worker, the IOC, or the environment

The maintenance hoist in the emergency generator rooms are designed to be used for general maintenance purposes. Lifts over principal SSCs are only expected during maintenance on the principal SSCs.

11.10.3 Major Components

The crane in the fresh fuel cask shipping truck bay (Room D-101) is a top-running, double-girder bridge crane, with electric bridge, trolley, and hoist drives. The rated capacity of the crane of 15 tons is specified to envelop the weight of all anticipated loads including a fully loaded fresh fuel cask and associated lifting devices, plus design margins specified in Crane Manufacturers' Association of America (CMAA)-70.

The crane in the assembly loading area (Room B-183) is a bridge crane that supports two, independent single girder underhung monorail hoists. The rated capacity of each of the assembly loading area hoist is 5 tons and is specified to envelop the weight of a fully loaded strongback and associated lifting devices, plus design margins specified in CMAA-74.

The crane in the fresh fuel cask handling area (Room B-185) is a top-running, single girder bridge crane, with an under-running hoist and electric bridge, trolley, and hoist drives. The rated capacity of 10 tons is specified to envelop the weight of all anticipated loads including a fully loaded fresh fuel cask and associated lifting devices, plus the design margins specified in CMAA-74.

The stacker crane in Room B-254 is a top-running, single girder bridge crane, with an under-running trolley and load mast, and with electric bridge, trolley, and load mast drives. The rated capacity of 3 tons is specified to envelop the weight of a pallet with four fully loaded waste drums plus the design margins specified in CMAA-74.

The maintenance hoist in the emergency generator rooms are each 6 tons and will be installed over the generator.

Lifting devices for fresh fuel shipping casks are designed in accordance with ANSI N14.6, "Radioactive Materials – Special Lifting Devices for Shipping Containers Weighing 10,000 lbs or More." Lifting devices for handling loads not covered by ANSI N14.6 comply with ANSI/ASME B30.9, "Slings," and ANSI/ASME B30.20, "Below-the-Hook Lifting Devices."

Other heavy lift cranes (if any) identified during detailed design will be described in the ISA.

11.10.4 Control Concepts

The stacker crane in Room B-254 is normally operated in automatic mode. The operator may also intercede via a local manual mode in which the interlocks are active in case of trouble in the automatic mode or for maintenance operations.

The crane in the assembly loading area in Room B-183 is operated in the automatic mode for transfer of the strongback between the assembly loading station and the strongback handling station. All other operations are locally controlled by an operator using a radio control station.

All other heavy lift cranes in the MFFF are locally controlled by an operator using radio control stations. The physical configuration of the control stations is governed by ASME B30.2, "Overhead and Gantry Cranes."

11.10.5 System Interfaces

Interfaces between the heavy lift cranes and other facility systems include the basic structural connections between the crane runways and the supporting building walls and the ties to the normal electrical supply system, which provide power for the electric bridge, trolley, and hoist motors and brakes. If the control station is linked to the crane via radio communications instead of hard-wired electrical circuitry, the effects of interference between facility security, process monitoring, and control systems that operate using radio frequencies and crane controls are considered.

11.10.6 Design Basis for Non-Principal SSCs

The MFFF heavy lift cranes and their major components are designed, fabricated, and qualified to perform required functions in accordance with the following national codes and standards:

- Crane Design – CMAA-70, "Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes," 1994; and CMAA-74, "Specifications for Top Running and Under Running Single Girder Electric Overhead Traveling Cranes Utilizing Under Running Trolley Hoists," 1994
- Under-Running Hoist Design – ASME B30.16, "Overhead Hoists (Underhung)," 1998
- Crane Operation – ASME B30.2, "Overhead and Gantry Cranes," 1996, and ASME B30.20, "Below-the-Hook Lifting Devices," 1993
- Special Lift Device Design – ANSI N14.6, "Radioactive Materials – Special Lifting Devices for Shipping Containers Weighing 10,000 lbs or More," 1993
- Normal Lift Device Design –ASME B30.9, "Slings," 1996 and ASME B30.20, "Below-the-Hook Lifting Devices," 1993.
- Crane Design – ASME B30.11, "Monorails and Underhung Cranes," 1998
- Crane Design – ASME B30.17, "Overhead and Gantry Cranes (Top Running Bridge, Single girder, Underhung Hoist)," 1999
- Crane Seismic Design – ASME NOG-1, "Rules for the Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)," 1998
- Crane Seismic Design – ASME NUM-1, "Rules for the Construction of Cranes, Monorails, and Hoists (With Bridge and Trolley or Hoist of the Underhung Type)," 1996

For top running and gantry type credited with performing interaction prevention functions, structural members are qualified in accordance with CMAA-70 and ASME B30.2 for normal operational loads. For seismic loading, they are qualified in accordance with ASME-NOG-1.

For underhung cranes, jib cranes, and monorails credited with performing interaction prevention functions, structural members are qualified in accordance with CMAA-74 and ASME B30.11 or ASME B30.17 for normal operational loads. For seismic loading, they are qualified in accordance with ASME-NUM-1.

Multiple girder motor-operated bridge cranes are designed, fabricated, and furnished in accordance with CMAA-70 and mandatory requirements in ASME B30.2.

Single girder motor-operated bridge cranes are designed, fabricated, and furnished in accordance with CMAA-74 and mandatory requirements in ASME B30.17.

Single girder, underhung, jib cranes, and monorail trolleys are designed in accordance with ASME B30.11.

Below the hook lifting devices are designed in accordance with ASME B30.20.

Maintenance cranes and maintenance hoists are not qualified to retain their loads under seismic conditions. Special provisions (e.g., operator protective equipment, removal of radioactive material from glovebox) are in place for maintenance crane/hoist lifts. Criticality prevention elements need not be qualified to withstand maintenance load drops, since it is assumed that all, or significant quantities of, nuclear materials are removed from the glovebox system and/or area isolated during maintenance.

Permanently installed heavy lift cranes at the MFFF are located within the protected structure of the buildings and are protected by the building from design basis natural phenomena events, except seismic. Where MFFF heavy lift cranes can move over principal SSCs, they are qualified to remain in place under all design loading conditions, including design basis earthquakes. Heavy lift cranes include design features to retain the load in the event of a loss of electrical power.

11.10.7 Design Basis for Principal SSCs

Heavy lift cranes at the MFFF have not been identified as principal SSCs. With the exception of the floor of the building (which is a principal SSC), and emergency generator SSCs during maintenance there are no cases where a heavy load will be lifted over a principal SSC. Building floors are evaluated for dynamic loads, including drop loads, as described in Section 11.1. A drop of any load handled by a heavy lift crane would not result in consequences in excess of 10 CFR §70.61 performance requirements to the worker, the IOC, or the environment; therefore, none of the lifts of these loads are critical lifts. Any non-heavy lift load lifted over a principal SSC will follow the Material Handling Controls described in Section 5.6.2.3. Any lift of a fresh fuel cask will be performed only when the qualified impact limiters are installed, and the maximum lift height of the cask will be less than the fresh fuel cask qualified drop height.

All heavy lift cranes will be operated in accordance with Material Handling Controls as described in Section 5.6.2.3.

Specific IROFS controls will be identified in the ISA.

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14. EMERGENCY MANAGEMENT

This chapter addresses the need for an emergency plan for the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF). In accordance with 10 CFR §70.22(i), each applicant to possess in excess of 2 curies of plutonium in unsealed form, or for which a criticality accident alarm system is required, must provide either:

- An evaluation showing that the maximum dose to a member of the public offsite due to a release of radioactive materials would not exceed 1 rem effective dose equivalent or an intake of 2 milligrams of soluble uranium, or
- An emergency plan for responding to the radiological hazards of an accidental release of special nuclear material and to any associated chemical hazards directly incident thereto.

DCS expects to be able to demonstrate that an emergency plan for responding to the radiological hazards of an accidental release of special nuclear material and to any associated chemical hazards directly incident thereto is not required.

DCS commits to providing with the license application for possession and use of special nuclear material, an evaluation that demonstrates that the maximum dose to a member of the public would not exceed 0.01 Sv (1 rem) effective dose equivalent or an intake of 2 milligrams of soluble uranium in accordance with 10 CFR §70.22(i)(1)(i).

DCS will establish a protocol with the U.S. Department of Energy Savannah River Operations Office (DOE-SR) that will provide for integration with the existing Savannah River Site emergency preparedness program, including limitation of site access in the event of an emergency at the MFFF (see Section 1.1.2.1).

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